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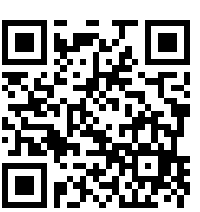

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MANUAL OF SEAMANSHIP

VOL. III

1951

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Volume III

B.R. 67 (3/51)

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B.R. 67 (3/51), *Manual of Seamanship, Volume III*, having been approved by My Lords Commissioners of the Admiralty, is hereby promulgated for the information and guidance of all concerned.

By Command of Their Lordships,

J. S. Long

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Preface

The *Manual of Seamanship* is divided into three volumes.

Volume I is intended to be used as a text-book for Naval Cadets and Seaman Boys who are under training at Shore Establishments, and Volume II by junior officers, Petty Officers, Leading Seamen, and by men desiring to qualify for advancement.

Both these volumes will also serve as books of reference for junior officers and senior ratings, and it is hoped that they will also prove useful and instructive to other professional seamen, yachtsmen, and all instructors of seamanship.

Lists of questions on the information given in each chapter have been included as an appendix to each of Volumes I and II, to give candidates for examination some idea of what they are expected to know and of the type of question they may be asked.

Volume III, herewith, comprises information on the more advanced aspects of seamanship, and is intended as a book of reference for seamen of experience.

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Contents

CHAPTER I

OFFICER-OF-THE-WATCH IN HARBOUR

Page

Gangway staff—Responsibilities—Remarks on responsibilities of the Officer-of-the-Watch 1

CHAPTER II

OFFICER-OF-THE-WATCH AT SEA

Knowledge of the lay-out of the bridge—Leaving harbour—Taking over a watch—The watch on deck—Seaboats—Lifebuoys and the lifebuoy sentry—Lookouts—Watertight integrity—Looking after the ship—Conning the ship—Navigation and pilotage—Low visibility—Indications of ice—Man overboard—Station-keeping, taking-up and changing station—Rule of the road—Sunset—Signals—Radar and Asdic—Logs and notebooks—Entering harbour—Reports to the Captain 15

CHAPTER III

RULE OF THE ROAD

INTERNATIONAL REGULATIONS FOR PREVENTING COLLISIONS AT SEA, 1948 32

CHAPTER IV

MANŒUVRING IN COMPANY

Turning definitions—Turning capabilities of ships—Tactical rudder—Unmooring and weighing—Turning "at rest"—Leaving harbour—Taking station in the column—Taking-up and changing station—Station-keeping—Keeping a plot 46

CHAPTER V

HANDLING SHIPS IN NARROW WATERS

MANŒUVRING IN GENERAL—Means of propulsion—Means of steering—Propeller action—Rudder action—Steering when going astern—Effects of loading—Effect of trim—Effects of shallow water—Handling of main engines—Effects of a wind—Gaining and losing speed—Use of berthing hawsers—Judgment of speed and distance ... 60

MANŒUVRING IN HARBOUR WITHOUT TUGS—Anchoring, riding at anchor, and weighing—Turning short—Turning short round an anchor—Securing to a buoy—Slipping from a buoy—Securing head and stern between two buoys—Slipping from a jetty—Going alongside, and slipping from, a ship at anchor or secured to buoys—Letting go an anchor before going alongside—Slipping from alongside with an anchor down—Entering and leaving harbour through a narrow entrance—Mooring stern to a jetty—Unmooring when secured by the stern to a jetty—Precautions, and action in emergency 69

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CHAPTER V—*cont.*

Page

MANŒUVRING IN A TIDEWAY AND A RIVER—Going alongside and slipping from a jetty—Passing through a narrow entrance—Manœuvring in rivers 99

MANŒUVRING WITH THE HELP OF TUGS—Girding—Going alongside—Slipping from alongside—Turning short—Navigating narrow channels 102

DOCKING AND UNDOCKING—Conditions required—Preparation in the ship—Docking hawsers—Preparations in the dock—Entering the dock — Docking — Docking-down — Flooding-up — Undocking—Floating docks—Docking small vessels with considerable trim—Docking destroyers—Docking submarines 104

MANŒUVRING IN A CANAL—Disturbance of the water and its effects on the ship—Steering the ship in a canal—Speed of the ship—Correcting a sheer—Passing another ship 110

CHAPTER VI

HANDLING SHIPS IN HEAVY WEATHER

Seas—Effect of the waves on the motion of a ship—Effect of the wind—Handling a ship in a seaway—Avoidance of tropical revolving storms—Making the ship seaworthy—Consideration of the crew—Use of oil to calm the sea—Blizzards—Sea anchors 116

CHAPTER VII

TOWING AT SEA

Towropes—Connecting and securing the towrope—Towing aids and preparations—Establishing contact and passing the towrope—Towing—Yawing—Towing alongside—Towing off a stranded ship—Towing an anchored and disabled ship off a lee shore 127

CHAPTER VIII

MOORINGS

Parts of a mooring—Types of moorings—Classification of moorings—Maintenance of moorings—Holding power of moorings—Hauling-off moorings—Swamping a mooring—Provision of telephone cables at moorings—Laying an anti-snatch mooring—Laying a resilient three-arm mooring 150

CHAPTER IX

SALVAGE OPERATIONS

Some legal aspects of salvage—First-aid to vessels afloat—Aid to vessels beached or stranded—Three examples of salving stranded vessels—Remarks on equipment, vessels and plant required for major salvage operations... 172

CHAPTER X

WRECK DISPERSAL

Locating a wreck—Marking a wreck—Surveying a wreck—Methods of dispersal—Laying and firing charges by boat—Laying and firing charges from the wreck dispersal vessel—Safety precautions—Precautions when operating inshore—Checking the clearance over a wreck by sweeping 200

Digitized by Google

CONTENTS

CHAPTER XI — *Page*

EXTEMPORE HANDLING OF HEAVY WEIGHTS

GYNS, DERRICKS, SHEERS, AND ROPEWAYS—Uses and limitations—Guys—Shoes—Heel tackles—Anti-twisters—Holdfasts—Raising derricks and sheers—Lowering derricks and sheers—Walking a derrick and sheers—Erecting a ropeway—Provision of power—Spars—Precautions—Data and formulæ for estimating stresses in derricks, sheers, and their rigging 212

SLEIGHS—Building a sleigh—Handling a sleigh 236

RAFTS—Buoyancy—Types of rafts—Floating a vehicle in a tarpaulin ... 247

CHAPTER XII

FIRE-FIGHTING

Organisation—Direction of operations—Additional fire-fighting hazards in ships—Potential causes or sources of fire—Emergency pumping—First-aid for burns—Fire-fighting arrangements in merchant ships ... 251

CHAPTER XIII

ABANDONING SHIP, SURVIVAL, AND RESCUE

ABANDONING SHIP—Importance of training—Maintenance of life-saving equipment—Importance of adequate clothing—Boats' provisions—Organisation for abandoning ship—Remarks on abandoning ship 267

SURVIVAL—Remarks on survival when adrift—First-aid—Notes for castaways 275

RESCUE—Methods of rescue and types of equipment—Treatment of survivors 295

CHAPTER XIV

WARSHIP CONSTRUCTION

Introduction—Shipbuilding materials—Methods of connection—Functions of the principal strength members—Watertight sub-division—Armour and protective plating—Submarines 301

CHAPTER XV

PUMPING AND VENTILATING SYSTEMS OF A WARSHIP

PUMPING, FLOODING AND DRAINING SYSTEMS, AND WATER SERVICES—Types of pumps—Arrangements for pumping out compartments—Salt water service—Flooding arrangements—Draining arrangements—Spraying arrangements—Valves and gearing—Fresh water systems in large ships—Fresh water systems in destroyers 340

VENTILATING SYSTEMS—Ventilation in arctic waters—Ventilation in the tropics—Methods of ventilation—Fans—Air supply terminals—Arrangements for preserving watertight integrity—Gas citadel—Organisation of ventilation 348

CHAPTER XVI

EQUIPMENT AND MAINTENANCE OF WARSHIPS

EQUIPMENT AND STORES 356

MAINTENANCE AND REFITTING—Defects—Alterations and additions—Maintenance—Refitting—Preparation for acceptance into reserve—Trials—Dockyard organisation 362

Digitized by Google

CONTENTS

CHAPTER XVII

TYPES AND DESIGN OF MERCHANT SHIPS, AND TONNAGE MEASUREMENT — *Page*

Types of merchant ships—Factors affecting the design of merchant ships—Tonnage measurement 380

CHAPTER XVIII

SHIP STABILITY

TRANSVERSE STABILITY—Righting moment—Transverse metacentre and transverse metacentric height—Position of the transverse metacentre—Degree of transverse stability—Stability at large angles of inclination—Rolling—Inclining experiment—Remarks on transverse stability 396

LONGITUDINAL STABILITY AND TRIM—Longitudinal metacentre—Longitudinal centres of buoyancy and gravity—Centre of flotation—Tons per inch immersion—Trim and change of trim—Moment to change trim one inch—Change of draught when passing from salt water to fresh water—Remarks on loading and trim... 412

STABILITY DATA AND THEIR USE—Stability data supplied to a cargo ship—Use of stability data—Stability data supplied to a warship—Remarks on flooding and countermeasures 418

STABILITY AND TRIM OF SUBMARINES—Transverse stability—Longitudinal stability and trim 431

CHAPTER XIX

CARGO STOWAGE

Glossary of terms—Planning the stowage of a general cargo—Remarks on stowing a general cargo 434

APPENDIX

DIMENSIONS AND STRENGTHS OF NYLON ROPE AND OF COMMON RIGGING FITTINGS 452

INDEX 470

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CHAPTER I

Officer-of-the-Watch in Harbour

THE DUTIES, responsibilities and powers of the Officer-of-the-Watch, both when at sea and in harbour, are laid down in the *Queen's Regulations and Admiralty Instructions*, and all officers of the executive branch should be thoroughly conversant with the relevant articles. In this chapter and the next some hints and remarks on the execution of these duties are given for the benefit of inexperienced watchkeepers.

Gangway Staff

Composition

The composition of a gangway staff depends upon the size and type of the ship and the time of day. In a large cruiser or a battleship, during the forenoon, afternoon and dog watches, it will usually comprise one or two midshipmen, a Quartermaster, a Boatswain's Mate, a Corporal-of-the-Gangway, one or two sideboys, one or two messengers and a bugler; during the night and morning watches, however, there will probably be only a Quartermaster, a Boatswain's Mate and a Corporal-of-the-Gangway. A small ship may have only a Quartermaster on watch both by day and at night.

Badges of Office

The Officer-of-the-Watch should wear a sword belt and carry a telescope, the Midshipman-of-the-Watch should carry a telescope, the Quartermaster and Boatswain's Mate should each wear a call and chain, and the Corporal-of-the-Gangway should wear a naval patrol armlet round the cuff of his left sleeve. By these badges of office the more important members of a gangway staff can be readily distinguished from other officers or ratings who may be on deck.

Duties

The staff should be alert and smart at all times, and never allowed to lounge about or talk idly to bystanders. Each member of the staff should carry out specific duties, the more important of which are detailed below.

The Midshipman-of-the-Watch should understudy the Officer-of-the-Watch and deputise for him when necessary. It is usual to delegate to him the running of the ship's routine and the boat routine, and he should always write up the ship's log and generally supervise the remainder of the gangway staff.

The Quartermaster should assist the Midshipman-of-the-Watch in his duties, and he should carry out these duties when there is no Midshipman-of-the-Watch. In addition, he should read the barometer and hygrometer and take the temperature of the sea at the required times, strike the time on the ship's bell every half hour except during the silent hours, pipe the routine and any other general orders, and call away the boats as required. He is in general charge of the after gangways and their accommodation ladders or brows, and should supervise the Boatswain's Mate, sideboys and messengers.

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The Boatswain's Mate assists the Quartermaster with his duties and calls reliefs. If a 'midship gangway is open as well as an after gangway he is usually in charge of the 'midship gangway and its ladder or brow.

The Corporal-of-the Watch keeps a security check on all incoming and outgoing packages and parcels, and on the wares of bumboatmen which are brought on board or taken out of the ship, to ensure that there is no illicit trafficking in dutiable or unauthorised goods or government property. He should check, in the *Gangway Duty Book*, all ratings proceeding on, or returning from, temporary duty ashore or in other ships. He should record in the *Gangway Wine and Spirit Book* (*S.251*) particulars of all wines, spirits, tobacco and other dutiable goods which are embarked or disembarked, and take charge of all correspondence other than Post Office mail and see that it is correctly delivered. He brings before the Officer-of-the-Watch any requestmen or defaulters below the rate of Petty Officer, and records all offences in the *Rough Report Book* (*S.242*). He should go the rounds between decks at least once every hour in each watch during the night and morning watches, and enter the time and any relevant information in the *Night Rounds Book* (*S.278*).

Equipment

In most ships the gangway staff are provided with a clock, and a desk under shelter on which to keep the ship's log and in which to stow the equipment necessary for their duties. This equipment should include the following :—

binoculars ; a plan or large-scale chart of the harbour or anchorage ; a ruler and protractors ; a tallied rack for the wireless and radar " safe to transmit/rotate " boards ; a hand lead-and-line ; a sea thermometer ; an Aldis lamp and battery ; a lantern and candles ; one or two electric torches and spare batteries ; a whistle ; codline, spunyarn and 20 fathoms or so of 2-in. cordage ; a small buoy or a billet of wood ; a pair of semaphore hand-flags ; a copy of the *Minor Landing Craft and Boat's Signal Book ;* the *Watertight Door and Hatch Board*, and the *Watertight Integrity Book* (*S.326*) *;* copies of the *Captain's Standing Orders* and the *Ship's Standing Orders ;* copies of miscellaneous permanent or temporary orders and memoranda, local or otherwise, relating to officer-of-the-watch duties in the ship, flotilla, squadron, fleet, or port ; washdeck and cleaning gear ; a note book, and an inventory of the gear in the desk.

In ships with more than a few officers an " officer's tally-board " is usually provided so that at any time it can be seen at a glance which officers are on board and which are out of the ship. The board is usually kept up to date by the Corporal-of-the-Watch.

Dress

The dress regulations for dutymen are in the *Appendix to the Navy List.* On ceremonial and special occasions, and on Sundays during the forenoon, afternoon and dog watches, the dress of the staff should be No. 1 or No. 10 ; during the same periods on weekdays it should be No. 2, No. 7 or No. 10. During the night and morning watches the dress may be No. 3, No. 8 or No. 10A.

Responsibilities

In harbour the Officer-of-the-Watch is responsible for :—

the safety of the ship ;

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B.R. 67(3/51) Vol. III—Manual of Seamanship—Amendment No. 1

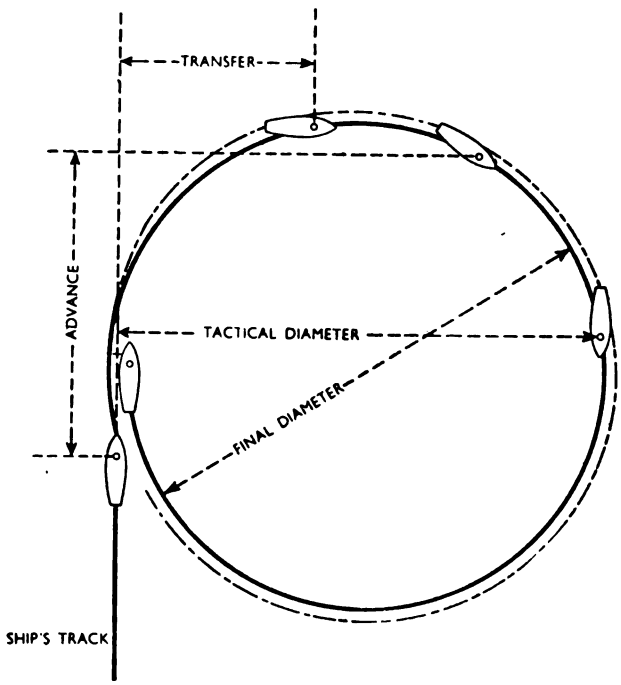
(D.N.D. 139/57.—8 Nov. 1957.)

Page 18. Seaboats. Line 11. *Delete* " ower " *insert* " lower ".

Page 23. Breakdowns. Third paragraph. Last line. *Amend to read* " to do so rests with the Bridge ".

Page 42. Rule 16. Paragraph 3. Line 2. *Delete* " operaitng " *insert* " operating ".

Page 47. Figure 2. *Delete* and paste over new figure.



Page 51. Line 10. *Delete* " her ", *insert* " your ".

Page 53. Line 21. *Insert* " relative " before " bearing ".

Page 61. Line 13. *Delete* " both sides of ".

Page 72. Lines 10 and 11. *Delete* " just as she gets her cable ", *insert* " when the required amount of cable is out ".

Page 80. Turning short round. Line 15. *Delete* " tauntened ", *insert* " tautened ".

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Page 93. *Add* at bottom of page.

" When there is risk of damage to either ship, the yawing ship should let go a second anchor ".

Page 95. Lines 12 and 13. *Delete* " the force ..... as required ", *insert* " then braked to prevent an impact with the jetty ".

Page 102. **Girding.** *Cancel* and *substitute :—*

Girding

A tug is said to be girded when she is towed broadside by her own towing hawser and is unable to manoeuvre out of this dangerous position.

Attention is drawn to the dangers to tugs by girding when the ship in tow attempts to give a kick ahead or astern by use of her main engines ; this is particularly so when the tug is towing on the beam, when a lack of judgment may manoeuvre the tug into a helpless position, possibly capsizing her.

Modern tugs have large engine power in relation to their size and towing hawsers proportional to their engine power ; consequently, if the tug is pulled laterally through the water with the towing hawser bearing out on the beam, it cannot be guaranteed that the hawser will part before the tug capsizes.

Although tugs are provided with slip hooks, there is some likelihood of the slipping arrangements failing to function when the tow is bearing athwart the tug.

Existing instructions state that slipping arrangements, for an emergency, are to be provided in the towed ship, but it should be remembered that a hawser under tension, when slipped from a high freeboard ship, may endanger the crew of the tug.

(*Amendment No. 1*)

Page 103. Slipping from Alongside. Lines 5 to 9. *Delete* " if the tugs are kept ..... head and stern tugs ", *insert :—*

" if the head tug is kept, the ship must not go ahead until the tug has moved ahead of her. If the stern tug is kept she will have to be resecured by her bow to be of any use ".

(*Amendment No. 1*)

Page 141. Messengers. Line 9. *Delete* " 123 " *insert* " 128 ".

Page 163. Swamping and Mooring. Line 13. *Delete* " transists " *insert* " transits ".

Page 218. Line 10. *Delete* " 53 ", *insert* " 55 ".

Page 232. At head of table *insert* " IN TONS " *after* " LOADS ".

Page 233.

Holdfasts. Line 1. *Delete* " 3 ft." *insert* " 3 in.".

Timber. *Delete* line 3 to the bottom of the page.

Page 259. Dangerous Gases. Line 16. *Delete* " toxicity " *insert* " toxic ".

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Page 260.

Line 1. *Delete* " details for the toxicity " *insert* " toxic values ".

6th line below table. *Delete* " 230 breathing apparatuses " *insert* " 5665 smoke mask ".

Page 265. Last paragraph. *Delete* " suitable types ..... smoke-helmet type ", *insert* " Pattern 5665 smoke mask is provided for use in smoke-filled spaces ".

Page 296. *Insert* facing page 296.

Rescue Harness (see figure 82a). The harness should be made by ship's staff of one thickness of R.N. No. 7 flax canvas, the belt 3 ft. by 1 ft. to lace round the waist and having two canvas straps crossed and attached at each end of the belt to form a support for the legs. The life-line should be spliced into the back.

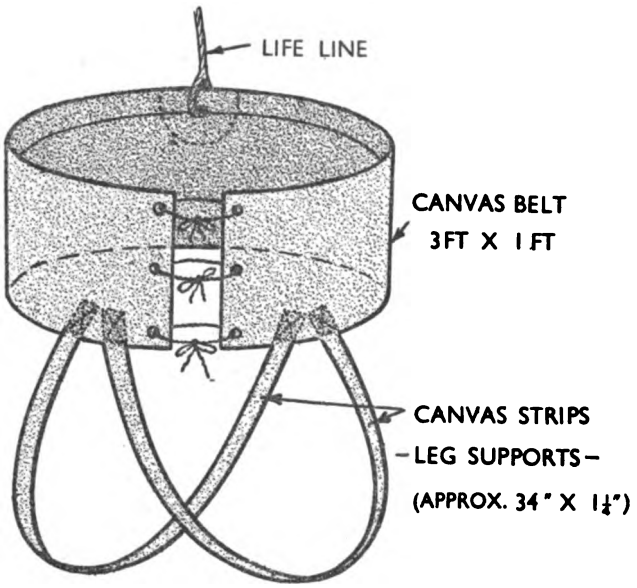

Fig. 82a

(*Amendment No. 1*)

Page 297. Methods of rescuing men from the sea. Sub-para. (iv). Line 1. *Delete* " an " *insert* " at ".

Page 432. Fig. 133. *Delete* " Longitudinal " *insert* " Transverse ".

Page 433. Fig. 134. *Delete* " Transverse " *insert* " Longitudinal ", *add* " a " after " of ".

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the safety of any men working over the ship's side, or working aloft ;
the safety of the ship's boats ;
the care of the ship's equipment ;
the appearance of the ship and her boats ;
the ordering of the ship's routine ;
the provision of boats for routine and out-of-routine trips ;
the safe embarkation and disembarkation of libertymen, ammunition, fuel, stores and provisions ;
taking the prescribed precautions in regard to wireless and radar equipment when ammunitioning or fuelling, or when men are going aloft ;
ensuring that visual signals are answered promptly and that no unauthorised signals are made ;
the security of the ship in regard to the entry or exit of unauthorised persons, and the prevention of smuggling or trafficking ;
the maintenance of the ship's watertight integrity ;
checking the issue and custody of important keys, and magazine keys ;
the investigation of disciplinary matters such as offences, representations, and the loss of stores ;
ensuring that the prescribed and customary marks of respect and courtesies are paid to officers and passing vessels ;
ensuring that the regulating staff maintain good order and discipline ;
ensuring that night rounds are carried out at least once every hour in each night watch ;
ensuring that the ship's log is written up correctly ;
instructing his subordinates in watchkeeping duties ;
seeing that the necessary precautions are taken when hands are piped to bathe alongside the ship.

Remarks on the responsibilities of the Officer-of-the-Watch

Information on taking over a Watch

Before taking over his watch the Officer-of-the-Watch should obtain the following information :—

(i) the scope of cable to which the ship is riding, whether she is at single anchor, moored, or made fast to a buoy ;
(ii) if the ship is at single anchor, whether a second anchor is ready for letting go ;
(iii) if the ship is at anchor or moored, the anchor bearings and particularly the bearing of any fixed object abeam ;
(iv) which boats are lowered ;
(v) which boats are away from the ship, what orders they have been given, and which boats, if any, are under sail ;
(vi) the employment of the hands, what routine is in force, what men, if any, are working over the side or aloft, and which watch or part of watch is on duty ;
(vii) which awnings are spread, and what windsails or washed clothes are up ;
(viii) whether the Captain and the Executive Officer are on board ; if they are not on board, who the commanding officer is for the time being ;
(xi) any special orders about boats, routine, or other matters ;
(x) the state of the weather and the barometer.

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Safety of the Ship

This can be dealt with under the four headings fire, collision, storm and tide.

Fire.—The Fire or Emergency Party should be mustered and reported to the Officer-of-the-Watch when they begin their turn of duty—usually at 1230. This is an important muster and should be correctly carried out. Whenever the ship is in a dockyard the Fire Party should be exercised daily after the dockyard workmen finish work for the day.

The Fire Party are usually allocated special sleeping billets in one space or compartment so that they can be roused at night at a moment's notice if required. If a fire occurs it is best to pipe the Fire Party to muster at a place clear of the fire and near the stowage for their gear; they can then be given instructions as to the nature of the fire and how best to tackle it. If a fire occurs when the ship is lying alongside in a dockyard the dockyard police should be informed immediately, to ensure that immediate assistance will be available should the fire spread or get out of hand.

Whenever dockyard workmen have been working between decks, the compartments and spaces in which they have been working should be inspected immediately after the workmen have left the ship, and again half-an-hour or an hour afterwards.

Whenever any vessel or lighter carrying explosives or inflammable cargo or stores berths alongside, all scuttles abreast her should be closed, the ship's company should be warned, and no smoking should be allowed on the upper-deck on the side against which she is berthed. If a lighter is to remain alongside after work in her is finished for the day, she should be inspected and then her hatches or hatchboards should be replaced, covered and battened down.

Whenever oil-fuel or explosives are being embarked or disembarked, in addition to the precautions detailed in the preceding paragraph, sentries should be posted and wireless transmission should cease. If petrol is being embarked or disembarked, all galley fires and incinerator fires should also be extinguished. In the event of a thunderstorm the embarkation or disembarkation of explosives, oil-fuel or petrol must be stopped well before the storm reaches the ship and not be resumed until it has passed. (For precautions in regard to wireless and radar aerials see page 10.)

Collision.—There is nothing one can do to avoid an imminent collision when the ship is at anchor or moored to a buoy except perhaps to veer cable.

If a collision appears possible or probable all watertight openings should be closed immediately by the order "D'ye hear there! Close all red and blue openings," and then the Emergency Party should be piped to muster.

As a routine precaution against collision during the night the watertight openings of a ship are brought to the same condition (XY) as when the ship is entering or leaving harbour, or manœuvring in company at sea. The requisite watertight openings are usually closed at the same time as the messdecks and flats are cleared up for rounds, and the normal day condition is resumed usually when the hands turn to in the morning, but only on specific instructions from the Officer-of-the-Watch.

If visibility deteriorates badly or fog closes down, the same watertight condition (XY) should be ordered, and the fog signal started.

Whenever the XY condition is ordered the fact should be recorded in the ship's log, the condition on the *Watertight Door and Hatch Board* should also be

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recorded, and strict control of the openings should be exercised, their opening and closing being recorded in the *Watertight Integrity Book* (*S.326*).

Storm.—In a storm the chief danger is that of dragging the anchors and drifting on to a lee shore or into another ship. When a gale is imminent the normal precautions are to raise steam, clear away the anchors and cables ready for veering cable and dropping a second anchor, and to set an anchor watch.

If there is any doubt about the anchors holding a bearing of any conspicuous fixed mark or light on shore should be taken, preferably one which is roughly abeam and not too far away ; any mark will do—a house or a chimney stack—and it need not necessarily be shown on the chart. The bearing should be checked frequently and if it draws forward it is certain the ship is dragging. To avoid dragging more cable should be veered, but it should be veered slowly and evenly under power so as to keep a steady strain on the cable ; if the cable is allowed to run out some fathoms at a time the jerk on the cable as the ship brings up to it each time will probably unbed the anchor.

If the ship is alongside a careful watch should be kept on the berthing hawsers, and any which appear to be bearing an undue strain should be doubled up.

Tide.—When the ship is alongside in a tidal harbour where there is an appreciable tidal range a careful watch should be kept on the berthing hawsers and brows as the tide rises and falls, especially during the third and fourth hours of a six-hour tide, when the rise or fall reaches its maximum rate.

Safety of Men Working Over the Side

Whenever men are working over the ship's side—when the side-party are touching up the boot-topping, for example, or when the hands are painting ship—vessels and boats passing close to the ship should do so at slow speed, and to ensure this it may be necessary to hoist the International Code signal *T.E.*

Whenever divers are at work, either from the ship's side or from a boat near by, the red flag must be hoisted at the appropriate yard-arm and the diving-boat should also display a red flag.

In a strong tideway no man should be allowed over the ship's side without the Officer-of-the-Watch's permission, and then only if he is wearing a life-jacket and has a lifeline round him which is tended inboard.

Safety of the Ship's Boats

At the Boat-booms.—Whenever a boat is made fast to a boat-boom the coxswain should report the fact personally to the Officer-of-the-Watch. All loose gear in the boat should be secured, the fenders should be placed (except on the outer side of a boat at the outer billet), no gear should be projecting or hanging outboard of the boat, and she should be riding comfortably with the correct amount of scope on her painter or boatrope.

It is the normal routine to hoist all boats except duty-boats in the dog watches, usually at 1800, and at the same time to reeve boatropes and sternfasts for those boats which are to remain down overnight. Hoisting boats, even as a matter of routine, should always be regarded as an evolution and carried out smartly. Boatropes are normally unrove when the hands turn to in the morning, unless the weather is rough.

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If the boats are bumping against each other or against the ship's side, or when the ship is swinging at the turn of the tide, the boatkeepers should be ordered to man their boats.

If a gale is imminent it is wisest to hoist all boats. If a boat has to be left down it is best to send her inshore to shelter before the weather gets too rough, if there is a safe berth for her there. If it is impracticable to send the boat inshore for shelter she should be made fast astern, because she will ride more easily there than at the lower-boom. If the seas are breaking heavily a little oil dripped continuously from a bag slung over each bow of the ship will calm the seas considerably and stop them breaking.

When alongside.—A boat should never be allowed to lie alongside for longer than is strictly necessary; she should be ordered either to make fast to a boat-boom or to lie off.

When a boat comes alongside, the gangway boatrope should always be lowered to her, and she should always make fast to it. It is unseamanlike to allow a boat to lie alongside unless secured to the boatrope.

In a strong tideway a tide-spar should be rigged before the foot of the accommodation ladder to prevent boats from getting jammed under it.

If the ship is moored head and stern to buoys in a tideway tide-spars should be rigged abaft the foot of the accommodation ladder as well as before it, and an extra boatrope should always be rigged abaft the ladder for use by boats coming alongside head to stern.

Precaution before leaving the ship.—Before a coxswain is ordered for the first time to go to a landing place he should be shown the plan of the harbour or anchorage, his course there and back, and any navigational dangers along his track. If the course is long and complicated he should be provided with a plan of the harbour or a tracing of it.

All coxswains of boats should know the times of high and low water, the range of the tide, and the time of sunset. It is a good plan to post these conspicuously above the gangway desk.

Although the coxswain is primarily responsible for the state of his boat and her crew it is the duty of the Officer-of-the-Watch to see that the crew are properly dressed and the boat shipshape. When time allows it is advisable occasionally to check various items of a boat's equipment, such as the lifebuoy in power-boats, life-jackets for the boat's crew, the ground tackle, the boat's slings, and the boat's signal book. In rough weather each member of the crew should wear a life-jacket; any member of the crew who cannot swim should wear a life-jacket always. If a boat is to be away after sunset her navigation lights should be shipped and in working order. If a boat is to be sent on a long out-of-routine trip it should be ensured that she has sufficient fuel for the trip there and back.

Before a boat leaves the ship her loading is primarily the responsibility of the Officer-of-the-Watch. He should ensure that she is correctly laden and not over-laden, taking into account the experience of the crew, the weather, and the duty the boat is to carry out and he should give the coxswain specific instructions in regard to these matters. If there is a possibility of the weather deteriorating badly while the boat is away from the ship the coxswain should be definitely told whether or not he should attempt to return to the ship, where he

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can shelter if necessary, and the maximum load his boat should carry in rough weather.

No one should be allowed to take away a boat under sail unless he is known to be proficient in handling boats under sail.

When away from the ship.—The safety of a boat when away from her ship is the responsibility of whoever is in charge of her, but the Officer-of-the-Watch is responsible that a lookout is kept on the ship's boats and on all boat traffic in the vicinity of the ship, and he should render immediate assistance to any boat seen to be in difficulties. A particularly careful watch should be kept on boats under sail. In a busy fleet anchorage when the boat traffic is considerable, it is advisable to detail one of the messengers or a sideboy for these duties as lookout-boy.

An occasional signal made to the ship's boats when they are away from the ship will ensure that the coxswains keep a good lookout on the ship.

The Officer-of-the-Watch should ensure that there is some method of passing any urgent message to the coxswain of a boat when she is at a landing place which is out of sight of the ship or out of visual signalling range.

Care of the Ship's Equipment

As regards the ship's equipment the Officer-of-the-Watch's chief concerns are the accommodation ladders, the awnings when spread, the brows and berthing hawsers when the ship is alongside, and the armament, and his chief requirement in regard to these is to keep an eye on the weather and to take any necessary action in good time.

Remarks on the handling and care of awnings are given in Volume II of this manual, and the care of berthing hawsers and brows when alongside in a tideway has been mentioned in an earlier paragraph of this chapter.

In rough weather the accommodation ladders should be hoisted clear of the water if waves are breaking over their lower platforms, and a well-fendered jumping ladder should then be rigged well aft on each quarter where there will be the best lee for boats coming alongside.

When lying alongside in a tideway an eye should be kept on the security of the brows, and their lanyards be adjusted as necessary to ensure that the brows do not damage the ship's decks.

Guns should be covered and awnings sloped *before* it starts to rain, and awnings should be frapped or furled *before* it starts to blow.

Appearance of the Ship and her Boats

On first taking over and subsequently throughout his watch the Officer-of-the-Watch should ensure that everything is shipshape and in good order, particular attention being paid to the following points.

Colours.—The ensign, jack and masthead pendant or distinguishing flag, should be hoisted close up and their halyards be taut, and they should not be foul of staffs, mast or nearby rigging.

Halyards and gantlines on masts and yards, and the vangs of the gaff, should be taut.

Boat-booms should be square with the ship's side, both fore-and-aft, and up-and-down. The bights of boat-ropes, when rove and unoccupied, should be clear of the water.

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The ship's side should be clear and there should be no ropes or fenders over it. Any bumboats or shore boats should be kept well clear of the ship and such boats never be allowed to make fast alongside, astern, or to the anchor cable.

Accommodation ladders should be rigged squarely, and the checkline should be cheesed down on the lower platform and the end of the gangway boatrope be cheesed down on the upper platform. The supports of the lower platform should be kept clear of any flotsam such as cotton-waste.

Awnings should be taut and square. The hauling parts of the falls of the awning and earring tackles, if rove, should be cheesed down.

Davits of boats which have been lowered should be turned or canted inboard ; the lower block of each fall should be hooked to the foot of the opposite davit, and the falls then be rounded up and reeled up or neatly stowed.

Boatkeepers in boats at the boat-booms should not be allowed to lounge about in their boats. They should salute when marks of respect are paid to passing boats carrying senior officers.

Boats' crews should be correctly and uniformly dressed in the rig ordered and should wear their caps with the chin-stays down. The normal rig for boats' crews from 0800 to 1830 is No. 1, No. 2, No. 6 or No. 7, and from 1830 to 0800 night-clothing. The rig for crews of boats calling alongside foreign warships day or night should be No. 2, but if the boat is carrying the Officer-of-the-Guard between sunset and sunrise, her crew may be dressed in night-clothing.

When washed clothes are piped up they should be properly stopped to the clothes lines with no holidays between them, and the lines should then be triced well clear of the decks and hauled taut. When washed clothes are piped down, any articles of clothing unclaimed should be placed in the scran-bag. No washed clothes should be allowed up at other than the routine times or in other than the prescribed places. If other ships are present a good watch should be kept on the flagship, or Senior Officer's ship, for any out-of-routine procedure such as spreading or furling awnings, covering or uncovering guns, and reeving boatropes, and her motions should be followed immediately.

Ordering of the Ship's Routine

The Officer-of-the-Watch is responsible that the routine is piped correctly and at the right time, and that the starred times are reported to the Executive Officer. The ship's company should always be warned well in advance of any change in the routine.

Out-of-routine pipes should be reduced to a minimum, and no out-of-routine order or information should be piped if it can be delivered equally well by messenger or passed by some other means.

Provision of Boats

The Officer-of-the-Watch is expected to see that boats are alongside the gangway before the times laid down in the boat routine, that their crews are called away at least ten minutes before these times. Coxswains of boats must report personally to him for orders before they man their boats.

It is usual to give warning of officers' routine trips by sounding one " G " on the bugle or one ring on the warning bell when the boat is called away, and by sounding two " Gs " or two rings when the boat is coming alongside. Liberty-men should be piped to fall in when the liberty boat is called away. The

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Officer-of-the-Watch should ensure that boats leave the ship punctually at the times laid down in the routine.

Boats should be refuelled at the times laid down ; if this is not possible plenty of warning must be given to the engine-room staff responsible for providing the fuel.

When a boat is required by the head of a department or other officer for an out-of-routine trip the provision of a boat for such a trip must not interfere with the boat routine ; if possible, such trips should be combined with routine trips. If in doubt on the advisability of providing a boat for an out-of-routine trip the matter should be referred to the Executive Officer or the Duty Commanding Officer.

Boats' crews should, as far as possible, be allowed the regulation periods for their meals. If a boat is likely to be away during a meal hour the galley staff should be warned in plenty of time so that the meal is not over-cooked but is kept hot until the return of the crew. If a boat is away during the dinner-hour the spirit ration of the crew should be drawn and placed in charge of the Officer-of-the-Watch.

A night-boat's crew is always detailed every night to man one of the boats in an emergency, such as " man overboard." The boat selected is usually a whaler or a dinghy, and if it is hoisted it must be ready for lowering instantly and lowerers must be detailed as well as the crew. The night-boat's crew and lowerers should sleep together so that they can be roused immediately in an emergency.

Despatch Boat

When in company with other ships the Senior Officer will detail one ship daily to provide a despatch boat to collect fleet correspondence from each ship and deliver it to the Senior Officer's ship, and to collect fleet correspondence from the Senior Officer's ship and distribute it among the other ships. The ship providing the boat also provides a mail orderly, and the boat usually makes one collection trip and one delivery trip in both the forenoon and the afternoon.

A good lookout should always be kept for the despatch boat and she should never be kept waiting alongside for longer than is necessary.

All fleet correspondence should be ready well before the expected time of arrival of the boat on her collection trip. The mail orderly should always report to the Officer-of-the-Watch on deck and any correspondence is then handed over. Handing over or receiving mail at the foot of the accommodation ladder is a bad practice ; it may save a little time but often results in the mail being dropped between the ship's side and the boat.

Embarkation and Disembarkation of Men and Stores

Libertymen.—The Officer-of-the-Watch should always supervise the embarkation and disembarkation of libertymen at the gangway, maintain strict silence both on board and in the boat, and ensure that no boat is overloaded having regard to the state of the weather and the experience of the coxswain. It is the custom for senior ratings to enter or leave a boat before junior ratings. No one should be allowed to rest his arm or hand on the gunwale of an open boat. After sunset a group-light should be rigged at the gangway to illuminate the accommodation ladder and any boat alongside.

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When many libertymen are landed an officer may be landed with a pier patrol to act as a piermaster at the landing place and ensure the safe embarkation of libertymen in their boats.

When a boat returns to the ship with libertymen, particularly after dark, one of the gangway staff should be stationed on the lower platform of the accommodation ladder to assist men getting out of the boat when necessary. A careful watch should be kept for men who appear incapable of getting out of the boat unaided ; such men, and any who are utterly incapable, should be got out last of all and with lifelines round them.

When the ship is alongside, the approaches to the jetty end of the brows should be kept clear of obstacles, and at night they should be well illuminated. When the ship is in dock the dockside guardrails should always be in place, and at night the route to the brow should be kept clear and well lit.

Ammunition, Fuel, Stores and Provisions.—Before the arrival of a vessel or lighter alongside, there should be nothing projecting outboard in the way of the vessel or lighter, and, where necessary, davits and boats should be turned in, boat-booms housed, and accommodation ladders hoisted inboard. Fenders and catamarans should be placed in position, and a small berthing party be detailed (out of working hours the duty hands assisted by members of the gangway staff should be sufficient). An executive officer should always be in charge when ammunition, stores or provisions are embarked or disembarked.

The precautions to be taken against fire when embarking or disembarking explosives, oil fuel or petrol are mentioned on page 4 and precautions in regard to wireless and radar aerials are given below. When embarking or disembarking ammunition only the authorised slinging and hoisting gear should be used, and this should be tested before use.

When stores or provisions are to be embarked or disembarked the Supply Officer should be asked beforehand for details of their quantity and type so that the necessary number of men can be detailed for the job and the necessary gear be prepared. When embarking or disembarking stores or provisions a member of the supply staff should be present, and a net should be slung between the ship's side and the gunwale of the vessel or lighter to catch anything which may fall from the hoists. When embarking or disembarking mails or kit a member of the regulating staff should be present.

Precautions in regard to Wireless and Radar Aerials

Radio transmissions or the movement of rotatable radar aerials must be restricted in the following circumstances :—

(i) when men are aloft ;
(ii) when the ship is dressed overall ;
(iii) when explosives are being embarked or disembarked ;
(iv) when explosives are being handled on deck, *e.g.*, when testing or stowing primed and fitted mines and electrically-fired detonators, or fuzing shells or bombs ;
(v) when embarking or disembarking inflammable stores and fuels.

The necessary restrictions differ in each case, and the radio sets affected by each combination of circumstances will usually be detailed in the ship's orders. The definition of " aloft," as applied in this sense to the masts, funnels or superstructure, should be laid down in the ship's orders.

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Before any of these operations are begun the permission of the Officer-of-the-Watch must be obtained, and before giving permission he should send for the appropriate " safe to transmit " or " safe to rotate " boards, and keep them on the special rack provided until the operation is completed.

When two ships are berthed alongside each other, transmission on high power by one ship will probably affect the other. If one ship requires to transmit on high power the other ship should be warned so that she can take any precaution necessary.

If it is essential to transmit on a restricted radio set during the third, fourth, or fifth operations tabled above, all work or fuelling must stop, explosives mentioned in the fourth operation must be sent below, other explosives or inflammable stores must be placed at least six feet from any hoisting whips, and any fuelling hoses must be disconnected.

Supervision of Visual Signalling

All visual signals from other ships or from shore must be answered promptly. Any visual signal made from the ship must first be approved by the Officer-of-the-Watch who should keep a check on the signal traffic to ensure that no unauthorised or unnecessary signal is made.

Security of the Ship

The Officer-of-the-Watch is responsible for ensuring that no unauthorised person enters or leaves the ship, that no dutiable goods are smuggled through the gangways or over the ship's side, and that no illicit trafficking is carried on over the ship's side or through scuttles.

The gangways should never be left unattended, and a check should be kept on all persons entering the ship and on all parcels or packages taken into or out of the ship. An occasional check should be kept on boats' crews returning on board by way of the boat-booms. Bumboats and shore boats should be kept well clear of the ship ; in some harbours it may be necessary to station a sentry on the forecastle to prevent people from climbing on board by way of the cable, and it may be necessary to use hoses to keep bumboats clear of the ship.

Fishing may be used as a cloak for smuggling or trafficking and fishing from scuttles is therefore prohibited and only allowed on deck by permission of the Officer-of-the-Watch.

At night it is usual to leave only one or two gangways open. If a gangway is closed its guard rails should be set up and its accommodation ladder hoisted, or its brow be hauled inboard or hauled on to the jetty.

Maintenance of the Ship's Watertight Integrity

Except in undefended harbours in war, the maintenance of the ship's watertight integrity is usually under the control of the Officer-of-the-Watch, who for this purpose is provided with a *Watertight Door and Hatch Board* on which to record the existing watertight condition of the ship, and a *Watertight Integrity Book* (*S.326*) in which to record the opening and closing of those watertight openings which should normally be kept closed. The Officer-of-the-Watch should keep strict supervision on the opening and closing of watertight openings, particularly during the night and in fog.

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Important Keys and Magazine Keys

Important keys.—Keys of important compartments or cupboards, such as those of the spirit room, the poison cupboard and the pistol cupboard, are kept in a special stowage known as the " important keyboard." A book is also provided showing the names of persons to whom particular keys may be issued, and in which should be recorded particulars of the issue and return of each key and the initials of the person concerned.

In all but small ships the keyboard and its book are placed in the Captain's lobby under the charge of the Captain's sentry. In small ships the important keyboard and the magazine keyboard are combined ; this keyboard is fitted in the quartermaster's lobby and is under the charge of a Branch Officer.

The key of the poison cupboard may only be issued to the Medical Officer, or, with the Officer-of-the-Watch's permission, to the Medical Officer's approved representative. If it is issued to the representative its return must be reported to the Officer-of-the-Watch.

Magazine keys.—The term " magazine keys " includes the keys of all compartments in which explosives and projectiles are stowed or handled. These keys are kept in a special stowage known as the " magazine keyboard " and their issue and return are recorded in the " magazine log."

In all but small ships the keyboard and log are placed in the Captain's lobby under the charge of the Captain's sentry. In small ships the combined magazine and important keyboard is placed in the quartermaster's lobby, together with the magazine log, the keyboard being under the charge of a Branch Officer.

At the end of each watch the Officer-of-the-Watch should examine the magazine log to ascertain whether :—

(i) the records of the issue of keys agree with the state of the keyboard ;
(ii) the records of magazine rounds during his watch have been entered and signed for ;
(iii) the records of magazine temperatures have been entered during his watch ;

and he should sign the log when he is satisfied that it has been correctly kept. If the log has been incorrectly kept he should inform his relief who should take the necessary action to have the log completed correctly.

In small ships the Officer-of-the-Day examines and signs the magazine log in a similar manner when he is relieved of his duties.

Investigations

The quarterdeck is the recognised place for the investigation of disciplinary matters, and the Officer-of-the-Watch is responsible for the primary investigation of all such matters. He should not, however, allow such investigations to interfere with his other duties ; if the investigation of a case appears likely to be long and complex he should ask for a relief to carry out his other duties or ask for another officer to investigate the case.

Charges.—Care should be taken to ensure that any charge preferred against a man is worded correctly. Before the Officer-of-the-Watch interrogates the accused in serious cases which may lead to a court martial, he should read to him the prescribed warning in regard to any evidence he may give. Charges against petty officers and serious charges against other ratings should be preferred by a regulating petty officer, and charges against chief petty officers should if possible

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be preferred by the Master-at-Arms. Any charge against a senior rating should, whenever practicable, be investigated in a place clear of onlookers.

Search.— Chief petty officers and petty officers are exempt from personal search unless it is specifically ordered by the Executive Officer or the Captain. Leading ratings are exempt from personal search unless it is specifically ordered by the Officer-of-the-Watch, the Executive Officer or the Captain. If a man's kit is searched the man and his divisional officer, or another officer, should be present at the search ; if no officer is available the kit should be searched on the quarterdeck under the supervision of the Officer-of-the-Watch.

Drunkenness.—The decision as to whether or not a man is drunk rests with the Officer-of-the-Watch, and the criterion in regard to drunkenness is whether or not the man is fit to carry out his normal duties. If, however, there is any doubt whether the man's condition is due to alcohol or to some other cause the advice of the Medical Officer should be obtained. Any altercation with a drunken man should be avoided and care must be taken to prevent him from aggravating his offence.

A drunken man should be placed in confinement to prevent him from aggravating his offence, and from injuring either himself or his messmates. Before a man who is incapable is placed in confinement he should be examined by the Medical Officer because when in such a condition he may require medical attention. Whenever a man is placed in confinement the Commanding Officer and the Executive Officer should be informed. If a man is only slightly drunk and is not excitable he may be sent to his mess under the care of two of his messmates. A drunken man who has been placed in confinement or under restraint should be released as soon as he is considered to be sober.

Fighting.—When investigating cases of fighting or altercation the participants should be kept well apart from each other to prevent any further outbreak of violence. If the difference between the two cannot be settled, and if they are of equal rate and appear well matched physically, they may be offered the opportunity of settling the argument by fighting it out in a boxing ring under the supervision of an officer.

Loss of Stores.—The loss of any stores or equipment, either by accident or neglect, must be investigated by the Officer-of-the-Watch, and the loss must be recorded in the ship's log.

Marks of Respect

The Officer-of-the-Watch is responsible for ensuring that the necessary marks of respect are paid to passing ships or boats carrying senior officers, and to officers arriving on board or leaving the ship. Remarks on salutes and other marks of respect are given in Chapter XIV of Volume I, and Chapter XVII of Volume II of this manual.

If a boat carrying a senior officer approaches, and the Captain is out of the ship, the Officer-of-the-Watch should, as a matter of courtesy, go to the foot of the accommodation ladder as the boat comes alongside and tell the senior officer that the Captain is away.

In a busy fleet anchorage it is advisable to detail a lookout-boy to keep a watch for approaching ships, and for boats flying distinguishing flags or pendants.

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Regulating Staff

It is laid down in the *Queen's Regulations and Admiralty Instructions* that the Executive Officer or the Officer-of-the-Watch is responsible that the regulating staff carry out their duties. The term " regulating staff " includes any rating performing or assisting in regulating duties.

Night Rounds

The Corporal-of-the-Watch should go the rounds of the ship between decks at least once every hour during the night and morning watches and should record these rounds in the *Night Rounds Book*. The Officer-of-the-Watch should sign the *Night Rounds Book* at the end of his watch.

Ship's Log

The ship's log should be written up in accordance with the instructions on the inside of its front cover, and the Officer-of-the-Watch should initial the log at the end of his watch after ensuring that it has been correctly written up.

Instruction of Subordinates

The Officer-of-the-Watch is responsible for instructing sub-lieutenants, junior branch-officers and midshipmen in Officer-of-the-Watch duties.

Hands to Bathe

Whenever hands are piped to bathe alongside the ship a boat equipped with a lifebuoy attached to a lifeline should always be in attendance to go to the rescue of any bather in difficulties. A dinghy manned by two men is very suitable for the job, and it should be stationed about 50 yards from the ship to mark the outside limit of the bathing area. Bathing should be under the supervision of an officer, and should be allowed only on one side of the ship ; in tropical waters a good lookout should be kept for sharks.

Never allow bathers to get down-tide, or to leeward in a strong wind, or to swim outside the bathing area. If there is a swell, jumping ladders and scramble nets for bathers to climb on board should be rigged. The heads and gash-chutes on the side on which bathing is to take place should be closed ten minutes before the hands are piped to bathe.

Reports to the Captain

The following times or occurrences are usually reported to the Captain by the Officer-of-the-Watch :—

(i) the times of five minutes before hoisting and lowering the colours ;

(ii) any marked deterioration in the visibility or the weather ;

(iii) the arrival or imminent departure of a warship ;

(iv) a boat under way carrying a flag officer with his flag flying ;

(v) the approach of a boat carrying a captain ;

(vi) anything else of particular interest or importance.

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CHAPTER II

Officer-of-the-Watch at Sea

THE CHIEF responsibility of the Officer-of-the-Watch at sea, as in harbour, is the safety of his ship, but because events usually develop more quickly at sea than in harbour he must always be prepared to take immediate action on his own initiative. Taking the correct action in an emergency is largely a matter of thinking it out beforehand so that when the emergency arises you will do the right thing almost instinctively, and you should therefore cultivate a habit of considering the action you would take in various emergencies, such as "man overboard," which might occur during your watch. Except when manœuvring or in low visibility, critical situations seldom develop suddenly, and most can be foreseen and avoided by taking the necessary action n good time.

Most accidents at sea are caused by one or more of the following omissions or mistakes :—

(i) failing to take the correct action due to lack of a thorough knowledge of the rule of the road or the manœuvring regulations ;
(ii) failing to keep a good lookout ;
(iii) failing to take normal seamanlike precautions in circumstances such as low visibility ;
(iv) failing to check the ship's position, course and speed frequently when coasting ;
(v) failing to appreciate that a critical situation is rapidly developing ;
(vi) indecision as to the correct action to take.

The remedies for the first four are obvious. The *Regulations for Preventing Collisions at Sea* are reproduced in full in the next chapter, and remarks on their interpretation are given in Chapter XVIII of Volume II of this manual. Remarks on manœuvring in company are given in Chapter IV of this volume ; orders for the Officer-of-the-Watch are given in *Queen's Regulations and Admiralty Instructions ;* and the normal precautions to be taken in various circumstances are described later on in this chapter.

The last two faults are usually the result of inexperience or a reluctance to seek advice. When in doubt the Officer-of-the-Watch must call his Captain ; even calling him unnecessarily is better than risking the ship, *but he should always be called in good time* so that he can take the necessary action *before* a critical situation arises.

The Officer-of-the-Watch should never allow his attention to be distracted by minor duties from his chief responsibility, which is the safety of the ship. If he cannot afford the time to attend to some pressing but lesser matter he should not hesitate to ask for another officer to attend to it.

Knowledge of the Lay-out of the Bridge

Before keeping a sea watch for the first time in any ship an officer should thoroughly acquaint himself with the lay-out of the bridge, the position of each instrument, telephone, voice-pipe and switch, and the tone of the buzzer of each voice-pipe and telephone, so that in the dark he can immediately place his hand

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on the instrument he requires. In this respect particularly important items of bridge equipment are the telephones and voice-pipes, the gong-switch of the lifebuoys, the master-switch for the navigation lights, the wheel-order transmitter, and the lanyards of the sirens.

Leaving Harbour

The Officer-of-the-Watch should be on the bridge in sufficient time before the Captain to check that the Special Sea Dutymen are at their stations, and that the ship's log and any routine orders have been transferred from aft to the bridge. The Chief Quartermaster, helmsman, and telegraphmen should be in the forward steering position; a quartermaster should be at the secondary steering position; leadsmen should be in the chains; the Boatswain's Mate, the Corporal of the Watch, and a bugler should be at the forward broadcasting position; the forecastle telephone should be manned; there should be a messenger on the bridge; and if the ship is anchored or moored a signalman with handflags should be on the forecastle. In addition, when slipping from head-and-stern buoys or when unberthing from alongside, the quarterdeck telephone should be manned, and screw-flagmen should be stationed aft, one on each side. If leaving harbour with other ships in formation a speed-flagman with a set of numeral handflags should be stationed in each wing of the bridge.

The engine-room staff are responsible for testing the functioning of the main engines, the engine-room telegraphs, the steering gear, and the sirens; and the electrical staff are responsible for testing the functioning of the gyro-compass repeaters, and all electrical communications.

Immediately before the ship gets under way the order is given "Obey engine-room telegraphs," but only on direct orders from the Captain.

When the ship is clear of harbour the Special Sea Dutymen are relieved by the sea dutymen of the watch and the order is given to "lay-in the lead," but only on direct orders from the Captain.

Taking over a Watch

It is most important that a watch should be turned over thoroughly and conscientiously, and never in a casual fashion. Before any officer takes over a watch he should be given the information detailed below by the officer he is relieving.

On all occasions :—

(i) the course of the ship by gyro-compass and/or standard compass;
(ii) the error of the gyro-compass and/or the deviation of the standard compass for the course being steered;
(iii) what rudder, if any, the ship is carrying;
(iv) the speed of the ship and the engine revolutions required to maintain that speed;
(v) the maximum speed available, and the number of boilers which are alight;
(vi) what ships are in sight, and whether they are opening or closing;
(vii) the ship's position on the chart;
(viii) what sounding gear, if any, is in use;
(ix) the state of the weather, what weather may be expected, and what the barometer is doing;

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(x) what land and landmarks, if any, are in sight or expected to be sighted ;
(xi) what ships, if any, are expected to be met ;
(xii) any instructions contained in the *Captain's Order Book ;*
(xiii) whether asdic watch is being kept, and details of any radar watch which is being kept ;
(xiv) whether a plot is being kept ;
(xv) the signal and W/T watch which is being kept ;
(xvi) the watertight condition in force ;
(xvii) general information such as the employment of hands ; the routine in force ; which, if any, of the awnings are spread ; whether men are working aloft or over the side ; etc.

In addition by night :—

(i) if radar watch is being kept what ships, if any, have been detected by radar, whether their positions are being plotted, and whether they are opening or closing ;
(ii) whether the navigation lights are burning brightly or are dimmed ;
(iii) what lookouts have been stationed.

In addition when in company with other ships :—

(i) the disposition of the force ;
(ii) the identity and position of the guide ;
(iii) the ship's station and whether she is in station ;
(iv) the number of engine revolutions which have been found necessary to maintain station ;
(v) the signalled course and speed of the force, the operational speed and the stationing speed ;
(vi) the amount of rudder to be used to conform to the tactical diameter ordered.

In addition in low visibility :—

(i) whether the fog buoy has been streamed ;
(ii) the position of the fog buoy of the next ahead ;
(iii) what extra lookouts have been stationed ;
(iv) the probable identity of any sound signals within hearing, and whether they are opening or closing ;
(v) if radar watch is being kept what ships, if any, have been detected by radar, whether their positions are being plotted, and whether they are opening or closing ;
(vi) whether the fog light is burning.

When in company with other ships, if the ship is out of station you should not take over until the Captain has been informed and he has told you to take charge of the ship.

It is customary to go on the bridge in time to take over the watch at the hour. By night you should go on the bridge earlier than by day so that by the time you take over, your eyesight will be accustomed to the darkness. On a dark night in war time with ships darkened it will take at least a quarter of an hour to attain your full night vision.

When you take over the watch you should make it quite clear to your predecessor that you are doing so, *e.g.*, by saying " Right, I will take over now."

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After taking over you should :—

(i) check the course of the ship with the course the quartermaster is steering ;
(ii) check the compasses ;
(iii) check the engine-revolutions ;
(iv) verify the ship's position on the chart by bearings of any navigational marks which may be in sight ;
(v) check the ship's course on the chart, see that it is a safe one, and that it is laid off correctly.

The Watch on Deck

The relieving watch or part-of-the-watch on deck should be mustered five or ten minutes before the hour ; the Petty Officer of the Watch should then detail the seaboat's crew and lowerers and the reliefs for the sea dutymen, and then report the state of his watch to the Officer-of-the-Watch. In working hours in peace time all but the sea dutymen and the seaboat's crew and lowerers work with their part-of-ship ; the seaboat's crew and lowerers may, with the Officer-of-the-Watch's permission, be allowed to work in the vicinity of the seaboats.

No member of the watch on deck should be allowed between decks during his watch. Out of working hours and during the night watches they may shelter on the weather decks, but they must be ready to muster at a moment's notice. The watch on deck is always available to carry out such duties as taking soundings, streaming the fog buoy, streaming and handing the log, placing oil navigation lights, and preparing an anchor for letting go.

Seaboats

The coxswain of the seaboat's crew should inspect the seaboats at the beginning of his watch and should report their state to the Officer-of-the-Watch; he should also inspect them at intervals throughout his watch, and should report any change in their state. The seaboat's crew and lowerers should shelter close to the seaboats, and they should not be employed on duties which will take them away from the vicinity of the boats, such as taking soundings. During the night watches the seaboat's crew should be exercised at manning one of the seaboats once a watch. The time taken to man the seaboat should be recorded in the log.

If a seaboat is to be lowered it is the duty of the Officer-of-the-Watch to ower her and to hoist her again ; but he should not leave the bridge for this duty before obtaining permission to do so from the Captain.

Lifebuoys and the Lifebuoy Sentry

In small ships a lifebuoy with a buoyant electric light or a calcium flare is fitted outboard on each wing of the bridge.

In larger ships the lifebuoys are usually fitted on each side of the ship aft, and are under the charge of a lifebuoy sentry, who may be a seaman or a marine. The sentry has a telephone to the bridge, and near him is an electric gong which is operated from the bridge in accordance with the following code :—

one ring ... cast the starboard lifebuoy overboard ;
two rings ... cast the port lifebuoy overboard ;
three rings ... cast both lifebuoys overboard.

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The sentry should report to the bridge by telephone on taking over his watch, every half-hour during his watch, and when he is relieved.

Lookouts

In war the chief function of the lookouts is to guard against surprise from enemy air or surface attack, and their duties and stationing are part of the gunnery organisation of the ship and not part of the navigational organisation.

In peace the stationing of lookouts is the responsibility of the Officer-of-the-Watch. In clear weather it is customary by day to station one lookout at the fore masthead, and by night to station two lookouts, one in each wing of the bridge. In low visibility extra lookouts should be stationed, one in the eyes of the ship, and, if the fog is low-lying, one aloft. When in company in column formation an extra lookout should be stationed on the forecastle to watch the fog buoy of the next ahead, and one should be stationed right aft if there is a ship keeping station astern.

Lookouts should always be alert, and should be given specific instructions as to what they should report ; in a busy shipping lane, for example, they will probably not be required to report every ship or navigational mark. Lookouts usually do a trick of one hour ; they should hail the bridge every half hour, and each should report personally to the Officer-of-the-Watch on being relieved. In addition to reporting the sighting of all ships and navigational marks they should keep an eye on the navigation lights and report any which are not burning with the required brilliance. If only one lookout is stationed it is customary for him to watch over an arc extending from two points abaft one beam, through right ahead to two points abaft the other beam ; if two lookouts are stationed each watches over an arc extending from right ahead to two points abaft the beam on his own side ; if a watch abaft these arcs is required an extra lookout should be stationed.

Watertight Integrity

In war the watertight integrity of cruisers and larger ships at sea is controlled from A.B.C.D. Headquarters, where a continuous watch is kept ; but in destroyers and smaller ships the watertight integrity of the ship is controlled by the Officer-of-the-Watch. In peace the watertight integrity of cruisers and some larger ships may be controlled by the Officer-of-the-Watch.

The normal watertight condition of a ship at sea in peace is Condition X, but Condition XY should be assumed whenever the ship is entering or leaving harbour, when manœuvring in company, and also in low visibility. In war, XY is the normal condition, but it depends largely on the possibility or probability of attack by the enemy. In emergency the watertight openings are closed by the order " Close red and blue openings," and a signal on the ship's alarm rattlers.

When the Officer-of-the-Watch is in control of the watertight integrity of the ship he should exercise strict supervision of the opening and closing of doors and hatches, and never allow too many to be opened at a time in any one section of the ship. He should ensure that the necessary entries are made in the *Watertight Integrity Log*, and that the state of the openings is correctly recorded on the *Watertight Door and Hatch Board*.

When not in control of the watertight integrity of the ship the Officer-of-the-Watch should always know the watertight condition in force, and he should not

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hesitate to order a higher condition if he considers it necessary—in low visibility or in an emergency, for example.

It should be borne in mind that whereas the change from one watertight condition to another may be effected in a minute or so, the change from one damage control state to another may take considerably longer because it may involve considerable changes in ventilation, the starting or stopping of much auxiliary machinery, and the employment of men other than those actually on watch.

Looking after the Ship

This includes not only preventing the ship and her equipment from being damaged but also ensuring the safety of men on deck and the comfort of those below, and controlling all matters which may affect the ship's routine.

When the ship is in a seaway a careful watch should be kept on her behaviour, and if she appears to be labouring unduly appropriate action should be taken before she suffers damage. Remarks on handling ships in rough weather are given in Chapter VI of this volume.

A careful watch should be kept on the weather, particularly in the tropics where calm periods may suddenly be broken by heavy rain squalls. The Officer-of-the-Watch should know the employment of the hands on deck and the state of the upper deck equipment, so that when a squall approaches he can take the appropriate action.

If men are working on the forecastle a careful watch must be kept on the ship's behaviour, particularly when heading into a low ground-swell in calm weather; such conditions are particularly treacherous because the pitch of the ship may synchronise with the period of the swell with little warning and she may then ship a green sea.

In calm weather, and particularly at meal times, warning should be given when possible of any sudden alteration of course which will heel the ship unduly. In rough weather warning should be given, when possible, of any alteration of course which will unduly increase the motion of the ship, as when turning broadside on to the sea, for example.

During the night watches, and particularly in rough weather, rounds must be conscientiously carried out both below and above decks every hour or half-hour. Those who go the rounds should look out for leaking hatches or scuttles, the security of equipment, particularly on the weather decks, and any potential fire risks.

A check should be kept on the carrying out of the ship's routine, and good warning be given of any change in it. It is most important to warn heads of departments as early as possible of any changes of the ship's programme such as an alteration of the time of arrival in harbour.

Conning the Ship

Orders for the wheel and engines should always be given loudly, clearly, decisively, and in the correct terms, in order to avoid any misunderstanding. For the same reason they should always be repeated back correctly.

Engine Orders

The wording of engine orders has been standardised for the sake of uniformity and the avoidance of phonetic errors, such as confusion between the words

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" port " and " both." The underlying principle is that the word *engines* is always used in conjunction with the words ***both or all***, but on no other occasions.

Examples :—

(i) Applicable to ships with two or four propeller shafts :—

" Half ahead (or astern) both engines."

" Stop both engines."

" Half ahead port."

" Slow astern starboard."

" Stop port."

(ii) Applicable to ships with three shafts :—

" Half ahead (or astern) all engines."

" Stop all engines."

" Half ahead port and starboard."

" Stop port and centre."

" Full ahead port."

" Stop starboard."

To avoid any possibility of confusion between a speed order and a wheel order the former should always be preceded by the word " revolutions " ; thus " Revolutions 120."

The usual method of the combined use of the engine order telegraphs and the revolution order telegraphs to control the speed of the engines is as follows :—

Slow	...	ahead or astern	...	a predetermined number of revolutions sufficient to give the ship steerage way—usually about 5 knots.
Half	...	ahead or astern	...	as indicated by the revolution order telegraph.
Full	...	ahead or astern	...	*emergency*—maximum revolutions possible with the power available.

The revolution order telegraphs are therefore only obeyed when the engine order telegraphs are at half speed ; the order " Full speed " being reserved for emergencies, and obeyed immediately with all the available power and without regard for possible damage to the machinery. The normal full speed with the power available is ordered by setting the required number of revolutions on the revolution order telegraphs. When manœuvring in harbour and in narrow waters it is usual to set on the revolution order telegraphs a predetermined number of revolutions corresponding to a half speed of from 8 to 10 knots ; if more or less speed ahead or astern is required it is best achieved by maintaining the engine order telegraphs at half speed and ordering the required revolutions on the revolution order telegraphs. It should be borne in mind when manœuvring that more steam is required to achieve a given number of revolutions astern than ahead, and consequently the maximum number of revolutions available astern are always appreciably less than the maximum number available ahead

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Each engine and revolution order is acknowledged from the engine-room by one or more strokes on the reply gongs in accordance with the following code :—

Slow ahead or astern	...	1 stroke
Half ahead or astern	...	2 strokes
Full ahead or astern	...	3 strokes
Stop	...	2 strokes (pause) 2 strokes
Revolution orders	...	1 or 2 strokes

Except when manœuvring the engine-room should always be given as much warning as possible if the engines are to be stopped ; otherwise the boilers may generate an excessive pressure and possibly be strained, and the safety valves will probably lift and create a lot of noise. For the same reason if the ship is to be stopped without warning it is best to reverse the engines without first stopping them. As a matter of interest when the engines are stopped with the ship making headway steam has usually to be applied to the astern turbines, otherwise the propellers will continue to revolve ahead.

The engine-room should also be given as much warning as possible of any large increase or decrease of speed which may be maintained for an appreciable period, and when cruising warning should be given in ample time if the ship is to be manœuvred.

Wheel Orders

When giving a wheel order the Officer-of-the-Watch should always glance at the rudder indicator to check that the wheel has been turned the correct amount in the required direction, and he should also check any engine order by glancing at the telegraph repeaters. The amount of wheel to use for altering course is usually laid down, either in squadron orders or in the Captain's orders. When turning in an emergency the orders " Hard a' port " or " Hard a' starboard " should always be avoided because these may so flurry the helmsman that he may put the wheel over the wrong way or too quickly.

Before making a large alteration of course the ship should be steady and not swinging, and immediately before ordering the wheel to be put over the order " Midships " should be given to ensure that the rudder is in its central position and to warn the helmsman to expect a wheel order. When turning in succession the rate of turning can be gauged by watching the bows and occasionally glancing at the compass. You should know from experience when to order opposite wheel to check the swing and how much to put on, and swinging past the new course should always be avoided. The order " steady " should never be given if the ship is swinging fast or has much wheel on, and the helmsman should always be conned to within 5 degrees of a new course.

An eye should be kept on the steering ; an occasional glance astern at the wake will show whether the helmsman is steering a steady course. The ship may be difficult to steer, particularly in a following sea, but the Officer-of-the-Watch must see that the helmsman does not let her yaw more to one side of her course than the other.

After putting on wheel the Officer-of-the-Watch should not leave the conning voice-pipe, or allow himself to be distracted, until he has steadied the ship on her new course. If he is unavoidably called away during a turn he should give the helmsman a course to steer before leaving the conning voice-pipe.

If a quick turn has to be made and it does not matter which way, it will be found that most ships turn more quickly into, than away from, the wind or sea.

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When turning precisely to a new course, in a narrow channel for example, the novice usually underestimates the " advance " and turns too late.

Breakdowns

Although modern mechanical and electrical systems are very reliable they occasionally break down. The Officer-of-the-Watch should have a thorough knowledge of the alternative systems of steering and of transmitting engine orders, and he should know what to do should the engines break down or one or more of the gyro-compasses fail.

The procedure to be followed if the steering gear fails is usually laid down in the Captain's orders and it should be carried out exactly, the quartermaster and other sea dutymen being given precise instructions. The Officer-of-the-Watch should know what actually has to be done when changing from one steering position to another, so that he can envisage each stage of the proceedings from the reports made to him. When first steering from a new position the quartermaster must be supervised closely, because unusual surroundings and different instruments might so confuse him that he puts the wheel over the wrong way, for example. If a twin-screw ship has to be steered by her engines it is usual to order a constant number of revolutions per minute for one engine and to vary those of the other.

If the engine-room wish to stop engines because of a breakdown they usually indicate it by continuously ringing the engine-order reply gongs If under the circumstances the ship can be safely stopped, this should be answered promptly by putting the telegraphs to " Stop," or serious damage may result, but as it may be dangerous for navigational reasons to stop, the decision whether or not to do so rests with Bridge.

In ships fitted with two or three gyro-compasses it is usual for the two steering repeaters each to be fed by a different compass ; similarly the Pelorus and the wing repeaters on the bridge are fed by different gyro-compasses. The Officer-of-the-Watch should always know from which particular gyro-compass the various repeaters are being fed, and by which repeater the ship is being steered, so that if one gyro-compass fails he will know immediately which repeaters are affected and which can be relied upon. The navigating officer and the gyro-compass electrician should at once be informed of a gyro-compass failure.

Navigation and Pilotage

The part played by the Officer-of-the-Watch in the actual navigation and pilotage of a ship depends largely on whether a navigating officer is borne, but no matter how small the part he plays he is always responsible for the safety of the ship. He should therefore keep himself informed of the ship's position and keep a check on her navigation or pilotage. No one is infallible and no instrument is absolutely reliable, and a conscientious check by the Officer-of-the-Watch on the navigation and pilotage of the ship is one of the greatest safeguards against a stranding caused by human error or a mechanical fault.

Every opportunity should be taken for checking the compasses for any error, either by a transit of navigational marks or by a bearing of the sun or a star. The gyro-compasses should be compared with each other and with their repeaters hourly, and also with the standard compass in ships fitted with magnetic compasses.

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A check should be kept on the actual course steered by the ship and if she is yawing or carrying rudder every effort should be made to ensure that the mean course steered agrees with the course ordered. The mean of the revolutions for each hour should be compared with the revolutions ordered, and the hourly log readings with the speed ordered.

The course laid off on the chart should be checked to ensure that it is a safe one. In pilotage waters every navigational mark should be identified as it comes in sight, and the position of the ship should be fixed at frequent intervals. The Officer-of-the-Watch should know the approximate strength and trend of any current or tidal stream, and should report immediately if the ship is being unduly set to one side or the other of her course. All fixes should be clearly recorded on the chart, and also in either the Officer-of-the-Watch's notebook or the Navigating Officer's notebook. When approaching land the Captain should be asked for instructions in regard to taking soundings and clearing away the anchors and cables.

When in formation with other ships in pilotage waters the wake of your next ahead should not be followed blindly, but a check on the position, course and speed of the ship should be kept, and the Officer-of-the-Watch should not hesitate to haul out of line if he thinks she is running into danger.

Low Visibility

When visibility closes down to within about a mile the precautions to be taken depend to a certain extent on whether a ship is alone or in company and whether it is peace or war. The normal action to be taken in peace is as follows :—

When alone :—

(i) reduce to a moderate speed ;
(ii) start sounding the fog signal, and ensure that the man who works the siren is equipped with a watch ;
(iii) set radar watch if the ship is equipped with radar, and start the plot
(iv) station fog lookouts ;
(v) inform the Captain and warn the engine-room ;
(vi) order watertight condition XY ;
(vii) maintain absolute quiet on the bridge and on deck, and if necessary stop fans or other noisy machinery in the vicinity of the bridge ;
(viii) have a signal projector ready for immediate use (a bright light can show surprisingly far in fog) ;
(ix) if in pilotage waters clear away an anchor ready for letting it go.

When in Column Formation.—The chief preoccupation of the Officer-of-the-Watch should be to maintain station. Orders in regard to speed and the sounding of the siren will probably be given by the Senior Officer of the formation. The following precautions should be taken in addition to those tabulated above :—

(i) set W/T watch ;
(ii) if a ship is astern of you in formation station a lookout aft, switch on the fog light, stream the fog buoy to a distance equal to four-fifths of the interval between ships, and prepare a second fog buoy ready for streaming ;
(iii) switch on navigation lights.

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In war reduction of speed, sounding the siren, and the display of lights will be governed by circumstances for which special orders are usually issued.

If, when alone and in peace time, you hear the fog signal of a vessel before the beam, take a bearing of the sound, stop engines, continue to sound one blast until all way is lost and then sound two blasts; remain stopped until you are sure the vessel will pass clear of you, and then go ahead again. When stopped you may sound the signal " R " if you wish the vessel to feel her way past you, but remember that this signal is supplementary to, and not an alternative for, the normal fog signal of a ship under way. From the time you first hear the vessel's fog signal until the way is off your ship you should not alter course, except to avoid a collision or a navigational danger; there is no rule against altering course in such circumstances, but in most cases of collision brought before the Admiralty courts the ship which has altered course without a sufficiently good reason has been blamed for doing so. If, after stopping engines and before your ship has lost her way, the bearing of the vessel's fog signal remains constant and appears to be approaching, you should at once take the way off your ship by putting the engines astern.

If your ship is equipped with radar do not place implicit faith in it and so neglect to take the normal precautions. Radar is not infallible and should be used as an aid to, and a check on, the normal methods of navigation.

Indications of Ice

The chief danger of drifting ice is that it is frequently accompanied by fog, and when steaming in regions where ice may be encountered a good watch should be kept for signs of the proximity of ice.

Signs of there being ice in the vicinity are as follows :—

Ice blink, which is a reflection of light from large masses of ice. On a clear day or night, and particularly on a moonlit night, the sky along the horizon in the direction of the ice is markedly paler or lighter in colour than along the remainder of the horizon.

Absence of sea or swell in a fresh breeze which, in the absence of land, indicates that ice is on the weather side.

Calf ice (small floes), this being a reliable sign of the close proximity of icebergs. When encountered in a curved line the parent berg will be on the concave side of the line.

Herds of seal or flocks of razorbills far from land.

Loud noises akin to gunfire or heavy breakers, these being caused by large masses of ice breaking off icebergs which are disintegrating.

Echoes from the siren, which may be received from nearby and high icebergs.

When steaming near icebergs it should be remembered that about seven-tenths or more of their mass is below water and may project horizontally near the surface for a considerable distance from their sides. If in low visibility an iceberg is sighted a short distance ahead the best avoiding action is to go full speed astern, because if you turn to avoid it the submerged and projecting ledges of the berg may then rip your bottom out.

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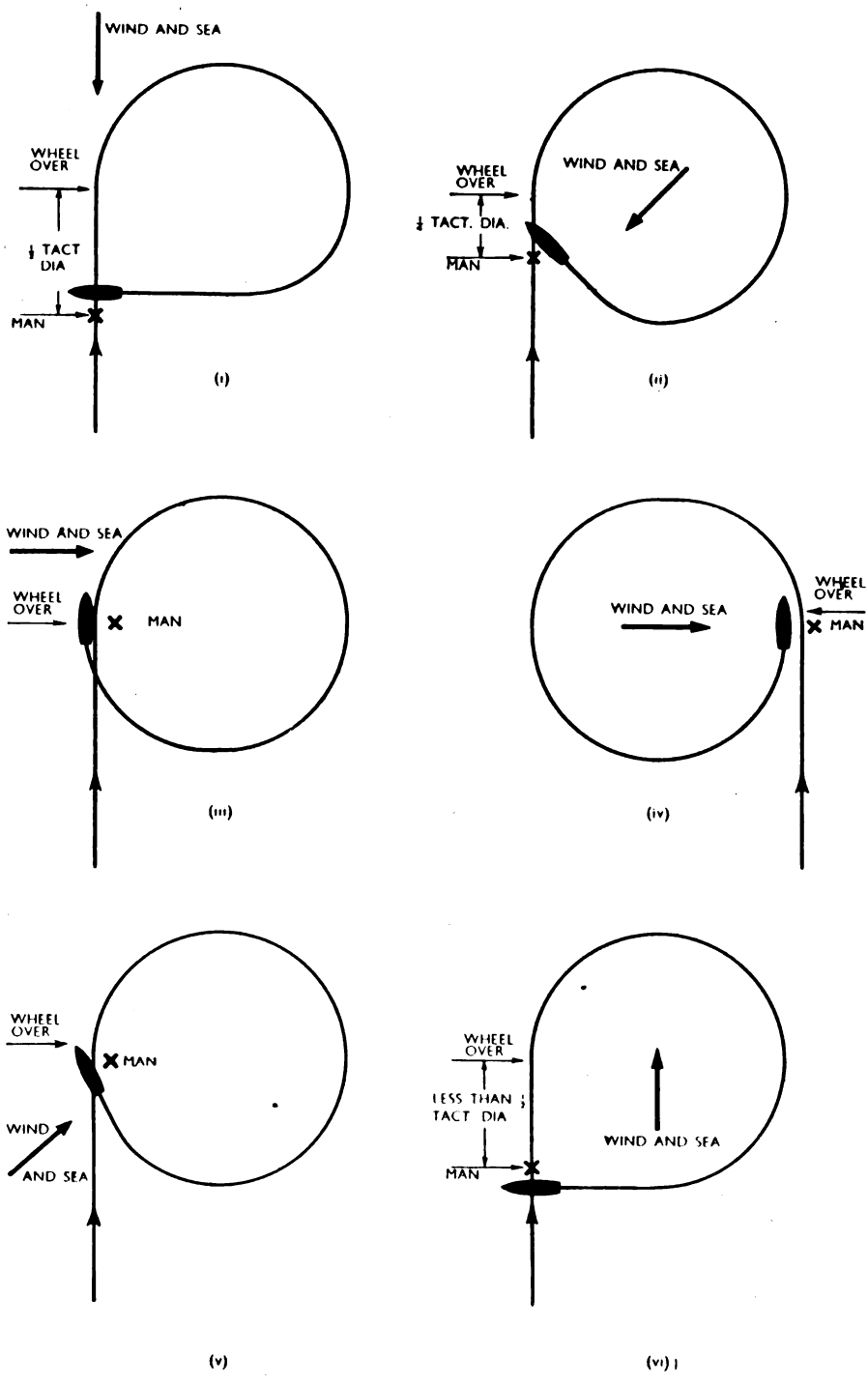

Fig. 1. Turning to pick up a man overboard

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Man Overboard

If a man falls overboard he will drift aft at a rate of about 8·3 feet a second for every five knots speed of the ship ; if, for example, a man falls overboard amidships from a destroyer steaming at 20 knots he will be about abreast the propellers in just under five seconds. Stopping the engines on the side from which the man fell to prevent him from being drawn into the propeller race will therefore be of little use unless the ship is steaming very slowly and the man fell from well forward, because even at 10 knots it will take at least 10 seconds to stop the propellers from the time the order is received in the engine-room.

For the same reason, putting the wheel over to the side from which the man fell in order to swing the stern away from him may be of little use unless the ship is steaming slowly, because the stern will not start to swing for at least five seconds after the wheel order is given. Experience has shown that provided the man comes up to the surface immediately after falling overboard he will probably float aft clear of the ship and her propellers, even if no action is taken to avoid him.

In calm weather, with little wind or sea and with the ship steaming at any speed other than slow, the best action to take if a man falls overboard is to increase speed and turn the ship through a full circle, using a larger amount of wheel during the last half of the turn than in the first. In the last stage of the turn, speed should be reduced and the ship brought to a stop abreast the man and heading on her original course. It is no use trying to turn the ship more quickly by reversing the inner propeller because the ship will then be brought to rest well ahead of the man (see Fig. 3 on page 49).

If the ship is steaming at slow speed, particularly a ship with good astern power such as a destroyer, it will probably be best to stop the ship by reversing the engines and then back astern to the man, but it should be borne in mind that the ship is not so manœuvrable when going astern and that the funnel smoke may well interfere with your view from the bridge.

In any appreciable wind and sea and at normal speeds the ship should be turned round to pick up the man, the turn being made so that she is brought to rest beam to wind and just to windward of the man.

With wind and sea dead ahead it is best to hold on for a distance equal to about half the ship's tactical diameter before putting the wheel over, and for the ship then to be steadied on a course at right angles with her original course after she has turned through 270 degrees (see Fig. 1 (i)).

With wind and sea on the bow the wheel should be put over a little earlier and the ship be turned towards the wind (see Fig. 1 (ii)).

With wind and sea abeam the wheel should be put over at once, and if the ship is turned away from the wind less wheel should be used during the last half of the turn than in the first half so as to ensure bringing the ship to rest to windward of the man ; for the same reason, if the ship is turned into the wind less wheel must be used during the first half of the turn than during the last half (see Fig. 1 (iii) and (iv)).

With wind and sea on the quarter the wheel should be put over at once and the ship be turned away from the wind ; after turning through 180 degrees the wheel should be eased to ensure bringing the ship to rest to windward of the man (see Fig. 1 (v)).

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With the wind and sea dead astern the ship should be held on her course, for a distance of a little less than half her tactical diameter, to allow for the drift of the man to leeward, before the wheel is put over (see Fig. 1 (vi)).

If steaming slowly into a head sea in rough weather it will probably be best to stop the ship by reversing the engines and then drifting down on the man. If the sea is abaft the beam particular care should be taken when stopping the ship not to gather sternway, otherwise the ship may be pooped and her propeller blades may be severely damaged if struck by a following sea

It should be remembered that the ship is more quickly manœuvred to the vicinity of the man than a boat, so the lifeboat should not be lowered until the ship is close to the man.

Station-keeping, Taking-up and Changing Station

Keeping the ship accurately in her station is most important, and it requires close attention and concentration on the part of the Officer-of-the-Watch. It is a common fault to be too easily satisfied, and nothing short of keeping exact station should be his aim.

Remarks on station-keeping and taking-up and changing station are given in Chapter IV of this volume, and these should be studied together with the " Manœuvring Regulations," of which latter the Officer-of-the-Watch should have a thorough knowledge.

Your next astern must always be remembered and he should be given ample warning of any large alterations of your speed or course. When entering or leaving harbour in column, when extreme accuracy in station-keeping is essential, it is usual to display speed flags from each wing of the bridge to indicate to your next astern any changes in the speed of the ship.

When changing station do not pass through a column or between columns without orders from the Captain, and avoid passing close ahead of a column. A captain junior to the senior officer of the column must ask permission to pass through the column, and a captain senior to the senior officer of the column must signal his intention of passing through the column.

Rule of the Road

The *Regulations for Preventing Collisions at Sea* are given in full in the next chapter, and notes on their interpretation are given in Volume II of this manual.

Your best insurance against collision with another ship is a thorough knowledge of the regulations coupled with a determination to avoid a collision whenever possible ; many a serious collision would not have occurred if the ship with the right-of-way had taken avoiding action when the situation became critical. The time at which a critical situation begins to develop depends on the speed of each ship and the angle at which they are converging ; if, for example, two ships one mile apart are each steaming at 10 knots nearly head on to one another and are on a steady relative bearing, they will collide in under 3¼ minutes if neither takes avoiding action. If, therefore, yours is the giving-way ship avoiding action should be taken in plenty of time, and if yours is the ship with right-of-way you should be prepared to take drastic avoiding action if the other ship approaches within a mile of you without altering course or speed.

If yours is the giving-way ship bear in mind Rule 22 of the *Regulations for Preventing Collisions at Sea* which says " Every vessel which is directed by these

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Rules to keep out of the way of another vessel shall, if the circumstances of the case admit, avoid crossing ahead of the other." You should therefore take avoiding action by turning to starboard or reducing speed, or both, or by reversing your engines. Only in exceptional circumstances would you be justified in turning to port or increasing speed.

In the open sea it is usually better to alter course than to reduce speed when taking avoiding action, because your avoiding action is then immediately evident to the other ship and because you do not lose so much ground. In narrow channels or crowded shipping lanes, however, it is usually better to reduce speed than to alter course, because altering course may not only take you across the tracks of nearby shipping and so complicate the situation, but it may take you unduly close to any navigational dangers, or even to the wrong side of the fairway.

In the open sea a common error of the novice is to alter course too soon and by too small an amount. If a ship is sighted to starboard on the horizon and she appears to be approaching you on a steady bearing wait until she is within five miles of you before altering course, and then do so boldly, altering by at least 20 degrees (to starboard) and do not resume your original course until you are certain you will pass well clear of her.

Sunset

Half an hour before sunset the Duty Electrician should test all electrically operated navigation lights, not-under-control lights and any other special lights, and should report their condition to the Officer-of-the-Watch.

Some ships are provided with oil-burning secondary navigation lights and not-under-control lights. These should be lit and shown to the Officer-of-the-Watch at sunset by the Petty-Officer-of-the-Watch and then placed ready to hand, care being taken that they cannot be seen from outboard.

Before sunset the Officer-of-the-Watch should ensure that rockets and any other pyrotechnic signals are placed or ready to hand, and that the visual signalling lights are in good order.

At sunset the Signalman-of-the-Watch should switch on the navigation lights and check that they are burning correctly, and a lookout should be placed in each wing of the bridge. The Officer-of-the-Watch should then report to the Captain the action taken.

Signals

The Officer-of-the-Watch is responsible for generally supervising the V.S. watch, for ensuring that signals from other ships are promptly answered and that no unauthorised signals are made, and for ensuring that important signals go immediately to those concerned. Every opportunity should be taken of conducting signal exercises with British merchant ships and any other merchant ships who may be willing to co-operate. When practicable, the names and destinations of passing warships and merchant ships should be ascertained and the particulars noted in the ship's log. Particular care should be taken to dip the ensign in reply to the salute of a passing merchant ship.

The Officer-of-the-Watch should know what wireless watches are being kept, and when on a long passage he should inform the wireless office hourly of the ship's position.

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Radar and Asdic

Radar can be of great assistance in navigation or pilotage, but it is just as liable to failure or error as any other mechanical or electrical contrivance. It should therefore be regarded as an aid to, or a check on, the normal methods of navigation and should not be relied on implicitly to the exclusion of the normal seamanlike precautions. When using radar for navigational purposes a good visual lookout should therefore always be kept at the same time, and if what is actually seen is at variance with what is indicated by radar the former rather than the latter should be relied upon. Whenever radar is being used a plot of the ship's course and of any echoes should also be kept.

Asdic is not normally used as an aid to navigation, but it has been used with success in low visibility to find the entrance to a harbour and to avoid submerged rocks and wrecks.

Logs and Notebooks

Navigator's or O.O.W.'s Notebook.—This is a small unruled notebook provided on the bridge for recording navigational data. In ships with qualified navigating officers one is usually provided for the Navigating Officer and one for the Officer-of-the-Watch. All bearings, sightings and fixes should be entered in this book at the time they are observed. On no account should such observations be recorded on odd scraps of paper because these may blow away and be lost.

Ship's Log.—Full instructions for writing up the ship's log are given on the inside of its front cover. Only sufficient navigational details should be entered in the log to enable the position of the ship throughout the watch to be checked, these details being transferred from the Navigator's or O.O.W.'s notebook. Check carefully all meteorological entries, and when estimates such as the force and direction of the sea are required make them yourself. You should complete the entries for your watch and sign the log before leaving the bridge.

Course Record Book.—In this should be recorded the courses steered, and the routine comparisons and checks of the ship's compasses.

Sounding Book.—In ships equipped with sounding machines all soundings taken by machine should be entered in the book.

Fishing Vessel Log.—This is only used in home waters and in it should be recorded details of all fishing vessels encountered. As full details as possible of any encounters should be recorded, otherwise it is difficult to substantiate or refute any subsequent claims for lost or damaged gear.

Entering Harbour

Before entering harbour, particularly after a voyage of any length, the sirens and the engine-room telegraphs should be tested. The Special Sea Dutymen and the Cable Party should be piped to their stations in good time, but in a seaway the Officer-of-the-Watch must not allow the Cable Party to go on the forecastle until he is sure it is safe for them.

Reports to the Captain

The following times or occurrences are usually reported to the Captain by the Officer-of-the-Watch :—

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On all occasions :—

(i) any marked deterioration in the visibility or the weather ;
(ii) any alteration of course in accordance with previous orders ;
(iii) any alteration of course to avoid another ship or a navigational danger ; this should be followed by a further report when the original course has been resumed ;
(iv) the sighting of land or navigational marks, as required by the Captain ;
(v) the sighting of any unidentified lights or marks, the failure to sight any lights or marks at the expected times, or the sighting of known lights or marks at unexpected times ;
(vi) the failure of any vessel approaching on a steady bearing from the port side to give way ; this report should be made before a critical situation has arisen ;
(vii) the sighting of another warship, if unexpected ;
(viii) the sighting of a wreck or wreckage ;
(ix) anything else of particular interest or importance.

In addition when in company with other ships :—

(i) any signalled alterations of course or speed ;
(ii) any alterations of the formation or disposition of the force.

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CHAPTER III

Rule of the Road

INTERNATIONAL REGULATIONS FOR PREVENTING COLLISIONS AT SEA, 1948

(*In force January* 1, 1954)

PART A. PRELIMINARY AND DEFINITIONS

Rule 1

(*a*) These Rules shall be followed by all vessels and seaplanes upon the high seas and in all waters connected therewith navigable by seagoing vessels, except as provided in Rule 30. Where, as a result of their special construction, it is not possible for seaplanes to comply fully with the provisions of Rules specifying the carrying of lights and shapes, these provisions shall be followed as closely as circumstances permit.

(*b*) The Rules concerning lights shall be complied with in all weathers from sunset to sunrise, and during such times no other lights shall be exhibited, except such lights as cannot be mistaken for the prescribed lights or impair their visibility or distinctive character, or interfere with the keeping of a proper look-out.

(*c*) In the following Rules, except where the context otherwise requires :—

(i) the word " vessel " includes every description of water craft, other than a seaplane on the water, used or capable of being used as a means of transportation on water ;

(ii) the word " seaplane " includes a flying-boat and any other aircraft designed to manœuvre on the water ;

(iii) the term " power-driven vessel " means any vessel propelled by machinery ;

(iv) every power-driven vessel which is under sail and not under power is to be considered a sailing vessel, and every vessel under power, whether under sail or not, is to be considered a power-driven vessel ;

(v) a vessel or seaplane on the water is " under way " when she is not at anchor, or made fast to the shore, or aground ;

(vi) the term " height above the hull " means height above the uppermost continuous deck ;

(vii) the length and breadth of a vessel shall be deemed to be the length and breadth appearing in her certificate of registry ;

(viii) the length and span of a seaplane shall be its maximum length and span as shown in its certificate of airworthiness, or as determined by measurement in the absence of such certificate ;

(ix) the word " visible," when applied to lights, means visible on a dark night with a clear atmosphere ;

(x) the term " short blast " means a blast of about one second's duration ;

(xi) the term " prolonged blast " means a blast of from four to six seconds' duration ;

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(xii) the word " whistle " means whistle or siren ;
(xiii) the word " tons " means gross tons.

PART B. LIGHTS AND SHAPES

Rule 2

(*a*) A power-driven vessel when under way shall carry :—

(i) On or in front of the foremast, or if a vessel without a foremast then in the forepart of the vessel, a bright white light so constructed as to show an unbroken light over an arc of the horizon of 20 points of the compass (225 degrees), so fixed as to show the light 10 points (112½ degrees) on each side of the vessel, that is, from right ahead to 2 points (22½ degrees) abaft the beam on either side, and of such a character as to be visible at a distance of at least 5 miles.

(ii) Either forward of or abaft the white light mentioned in sub-section (i) a second white light similar in construction and character to that light. Vessels of less than 150 feet in length, and vessels engaged in towing, shall not be required to carry this second white light but may do so.

(iii) These two white lights shall be so placed in a line with and over the keel that one shall be at least 15 feet higher than the other and in such a position that the lower light shall be forward of the upper one. The horizontal distance between the two white lights shall be at least three times the vertical distance. The lower of these two white lights, or if only one is carried then that light, shall be placed at a height above the hull of not less than 20 feet, and, if the breadth of the vessel exceeds 20 feet, then at a height above the hull not less than such breadth, so however that the light need not be placed at a greater height above the hull than 40 feet. In all circumstances the light or lights, as the case may be, shall be so placed as to be clear of and above all other lights and obstructing superstructures.

(iv) On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of 10 points of the compass (112½ degrees), so fixed as to show the light from right ahead to 2 points (22½ degrees) abaft the beam on the starboard side, and of such a character as to be visible at a distance of at least 2 miles.

(v) On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of 10 points of the compass (112½ degrees), so fixed as to show the light from right ahead to 2 points (22½ degrees) abaft the beam on the port side, and of such a character as to be visible at a distance of at least 2 miles.

(vi) The said green and red sidelights shall be fitted with inboard screens projecting at least 3 feet forward from the light, so as to prevent these lights from being seen across the bows.

(*b*) A seaplane under way on the water shall carry :—

(i) In the forepart amidships where it can best be seen a bright white light, so constructed as to show an unbroken light over an arc of the horizon of 220 degrees of the compass, so fixed as to show the light 110 degrees on each side of the seaplane, namely, from right ahead

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to 20 degrees abaft the beam on either side, and of such a character as to be visible at a distance of at least 3 miles.

(ii) On the right or starboard wing-tip a green light, so constructed as to show an unbroken light over an arc of the horizon of 110 degrees of the compass, so fixed as to show the light from right ahead to 20 degrees abaft the beam on the starboard side, and of such a character as to be visible at a distance of at least 2 miles.

(iii) On the left or port wing-tip a red light, so constructed as to show an unbroken light over an arc of the horizon of 110 degrees of the compass, so fixed as to show the light from right ahead to 20 degrees abaft the beam on the port side, and of such a character as to be visible at a distance of at least 2 miles.

Rule 3

(*a*) A power-driven vessel when towing or pushing another vessel or seaplane shall, in addition to her sidelights, carry two bright white lights in a vertical line one over the other, not less than 6 feet apart, and when towing more than one vessel shall carry an additional bright white light 6 feet above or below such lights, if the length of the tow, measuring from the stern of the towing vessel to the stern of the last vessel or seaplane towed, exceeds 600 feet. Each of these lights shall be of the same construction and character and one of them shall be carried in the same position as the white light mentioned in Rule 2 (*a*) (i), except the additional light, which shall be carried at a height of not less than 14 feet above the hull. In a vessel with a single mast, such lights may be carried on the mast.

(*b*) The towing vessel shall also show either the stern light specified in Rule 10 or in lieu of that light a small white light abaft the funnel or aftermast for the tow to steer by, but such light shall not be visible forward of the beam. The carriage of the white light specified in Rule 2 (*a*) (ii) is optional.

(*c*) A seaplane on the water, when towing one or more seaplanes or vessels, shall carry the lights prescribed in Rule 2 (*b*) (i), (ii) and (iii); and, in addition, she shall carry a second white light of the same construction and character as the white light mentioned in Rule 2 (*b*) (i), and in a vertical line at least 6 feet above or below such light.

Rule 4

(*a*) A vessel which is not under command shall carry, where they can best be seen, and, if a power-driven vessel, in lieu of the lights required by Rule 2 (*a*) (i) and (ii), two red lights in a vertical line one over the other not less than 6 feet apart, and of such a character as to be visible all round the horizon at a distance of at least 2 miles. By day, she shall carry in a vertical line one over the other, not less than 6 feet apart, where they can best be seen, two black balls or shapes each not less than 2 feet in diameter.

(*b*) A seaplane on the water which is not under command may carry, where they can best be seen, two red lights in a vertical line one over the other not less than 3 feet apart, and of such a character as to be visible all round the horizon at a distance of at least 2 miles, and may by day carry in a vertical line one over the other not less than 3 feet apart, where they can best be seen, two black balls or shapes, each not less than 2 feet in diameter.

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(*c*) A vessel engaged in laying or in picking up a submarine cable or navigation mark, or a vessel engaged in surveying or underwater operations when from the nature of her work she is unable to get out of the way of approaching vessels, shall carry, in lieu of the lights specified in Rule 2 (*a*) (i) and (ii), three lights in a vertical line one over the other not less than 6 feet apart. The highest and lowest of these lights shall be red, and the middle light shall be white, and they shall be of such a character as to be visible all round the horizon at a distance of at least 2 miles. By day, she shall carry in a vertical line one over the other not less than 6 feet apart, where they can best be seen, three shapes each not less than 2 feet in diameter, of which the highest and lowest shall be globular in shape and red in colour, and the middle one diamond in shape and white.

(*d*) The vessels and seaplanes referred to in this Rule, when not making way through the water, shall not carry the coloured sidelights, but when making way they shall carry them.

(*e*) The lights and shapes required to be shown by this Rule are to be taken by other vessels and seaplanes as signals that the vessel or seaplane showing them is not under command and cannot therefore get out of the way.

(*f*) These signals are not signals of vessels in distress and requiring assistance. Such signals are contained in Rule 31.

Rule 5

(*a*) A sailing vessel under way and any vessel or seaplane being towed shall carry the same lights as are prescribed by Rule 2 for a power-driven vessel or a seaplane under way, respectively, with the exception of the white lights specified therein, which they shall never carry. They shall also carry stern lights as specified in Rule 10, provided that vessels towed, except the last vessel of a tow, may carry, in lieu of such stern light, a small white light as specified in Rule 3 (*b*).

(*b*) A vessel being pushed ahead shall carry, at the forward end, on the starboard side a green light and on the port side a red light, which shall have the same characteristics as the lights described in Rule 2 (*a*) (iv) and (v) and shall be screened as provided in Rule 2 (*a*) (vi), provided that any number of vessels pushed ahead in a group shall be lighted as one vessel.

Rule 6

(*a*) In small vessels, when it is not possible on account of bad weather or other sufficient cause to fix the green and red sidelights, these lights shall be kept at hand lighted and ready for immediate use, and shall, on the approach of or to other vessels, be exhibited on their respective sides in sufficient time to prevent collision, in such manner as to make them most visible, and so that the green light shall not be seen on the port side nor the red light on the starboard side, nor, if practicable, more than 2 points (22½ degrees) abaft the beam on their respective sides.

(*b*) To make the use of these portable lights more certain and easy, the lanterns containing them shall each be painted outside with the colour of the lights they respectively contain, and shall be provided with proper screens.

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Rule 7

Power-driven vessels of less than 40 tons, vessels under oars or sails of less than 20 tons, and rowing boats, when under way shall not be required to carry the lights mentioned in Rule 2, but if they do not carry them they shall be provided with the following lights :—

(*a*) Power-driven vessels of less than 40 tons, except as provided in section (*b*), shall carry :—

(i) In the forepart of the vessel, where it can best be seen, and at a height above the gunwale of not less than 9 feet, a bright white light constructed and fixed as prescribed in Rule 2 (*a*) (i) and of such a character as to be visible at a distance of at least 3 miles.

(ii) Green and red sidelights constructed and fixed as prescribed in Rule 2 (*a*) (iv) and (v), and of such a character as to be visible at a distance of at least 1 mile, or a combined lantern showing a green light and a red light from right ahead to 2 points (22½ degrees) abaft the beam on their respective sides. Such lantern shall be carried not less than 3 feet below the white light.

(*b*) Small power-driven boats, such as are carried by sea-going vessels, may carry the white light at a less height than 9 feet above the gunwale, but it shall be carried above the sidelights or the combined lantern mentioned in subsection (*a*) (ii).

(*c*) Vessels of less than 20 tons, under oars or sails, except as provided in section (*d*), shall, if they do not carry the sidelights, carry where it can best be seen a lantern showing a green light on one side and a red light on the other, of such a character as to be visible at a distance of at least 1 mile, and so fixed that the green light shall not be seen on the port side, nor the red light on the starboard side. Where it is not possible to fix this light, it shall be kept ready for immediate use and shall be exhibited in sufficient time to prevent collision and so that the green light shall not be seen on the port side nor the red light on the starboard side.

(*d*) Small rowing boats, whether under oars or sail, shall only be required to have ready at hand an electric torch or a lighted lantern showing a white light, which shall be exhibited in sufficient time to prevent collision.

(*e*) The vessels and boats referred to in this Rule shall not be required to carry the lights or shapes prescribed in Rules 4 (*a*) and 11 (*e*).

Rule 8

(*a*) (i) Sailing pilot-vessels, when engaged on their station on pilotage duty and not at anchor, shall not show the lights prescribed for other vessels, but shall carry a white light at the masthead visible all round the horizon at a distance of at least 3 miles, and shall also exhibit a flare-up light or flare-up lights at short intervals, which shall never exceed 10 minutes.

(ii) On the near approach of or to other vessels they shall have their sidelights lighted ready for use and shall flash or show them at short intervals, to indicate the direction in which they are heading, but the green light shall not be shown on the port side, nor the red light on the starboard side.

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(iii) A sailing pilot-vessel of such a class as to be obliged to go alongside of a vessel to put a pilot on board may show the white light instead of carrying it at the masthead and may, instead of the sidelights above mentioned, have at hand ready for use a lantern with a green glass on the one side and a red glass on the other to be used as prescribed above.

(*b*) A power-driven pilot-vessel when engaged on her station on pilotage duty and not at anchor shall, in addition to the lights and flares required for sailing pilot-vessels, carry at a distance of 8 feet below her white masthead light a red light visible all round the horizon at a distance of at least 3 miles, and also the sidelights required to be carried by vessels when under way. A bright intermittent all round white light may be used in place of a flare.

(*c*) All pilot-vessels, when engaged on their stations on pilotage duty and at anchor, shall carry the lights and show the flares prescribed in sections (*a*) and (*b*), except that the sidelights shall not be shown. They shall also carry the anchor light or lights prescribed in Rule 11.

(*d*) All pilot-vessels, whether at anchor or not at anchor, shall, when not engaged on their stations on pilotage duty, carry the same lights as other vessels of their class and tonnage.

Rule 9

(*a*) Fishing vessels when not fishing shall show the lights or shapes prescribed for similar vessels of their tonnage. When fishing they shall show only the lights or shapes prescribed by this Rule, which lights or shapes, except as otherwise provided, shall be visible at a distance of at least 2 miles.

(*b*) Vessels fishing with trolling (towing) lines, shall show only the lights prescribed for a power-driven or sailing vessel under way as may be appropriate.

(*c*) Vessels fishing with nets or lines, except trolling (towing) lines, extending from the vessel not more than 500 feet horizontally into the seaway shall show, where it can best be seen, one all round white light and in addition, on approaching or being approached by another vessel, shall show a second white light at least 6 feet below the first light and at a horizontal distance of at least 10 feet away from it (6 feet in small open boats) in the direction in which the outlying gear is attached. By day such vessels shall indicate their occupation by displaying a basket where it can best be seen ; and if they have their gear out while at anchor, they shall, on the approach of other vessels, show the same signal in the direction from the anchor ball towards the net or gear.

(*d*) Vessels fishing with nets or lines, except trolling (towing) lines, extending from the vessel more than 500 feet horizontally into the seaway shall show, where they can best be seen, three white lights at least 3 feet apart in a vertical triangle visible all round the horizon. When making way through the water, such vessels shall show the proper coloured sidelights but when not making way they shall not show them. By day they shall show a basket in the forepart of the vessel as near the stem as possible not less than 10 feet above the rail ; and, in addition, where it can best be seen, one black conical shape, apex upwards. If they have their gear out while at anchor they shall, on the approach of other vessels, show the basket in the direction from the anchor ball towards the net or gear.

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(*e*) Vessels when engaged in trawling, by which is meant the dragging of a dredge net or other apparatus along or near the bottom of the sea, and not at anchor :—

(i) If power-driven vessels, shall carry in the same position as the white light mentioned in Rule 2 (*a*) (i) a tri-coloured lantern, so constructed and fixed as to show a white light from right ahead to 2 points (22½ degrees) on each bow, and a green light and a red light over an arc of the horizon from 2 points (22½ degrees) on each bow to 2 points (22½ degrees) abaft the beam on the starboard and port sides, respectively ; and not less than 6 nor more than 12 feet below the tri-coloured lantern a white light in a lantern, so constructed as to show a clear, uniform, and unbroken light all round the horizon. They shall also show the stern light specified in Rule 10 (*a*).

(ii) If sailing vessels, shall carry a white light in a lantern so constructed as to show a clear, uniform, and unbroken light all round the horizon, and shall also, on the approach of or to other vessels show, where it can best be seen, a white flare-up light in sufficient time to prevent collision.

(iii) By day, each of the foregoing vessels shall show, where it can best be seen, a basket.

(*f*) In addition to the lights which they are by this Rule required to show, vessels fishing may, if necessary in order to attract attention of approaching vessels, show a flare-up light. They may also use working lights.

(*g*) Every vessel fishing, when at anchor, shall show the lights or shape specified in Rule 11 (*a*), (*b*) or (*c*) ; and shall, on the approach of another vessel or vessels, show an additional white light at least 6 feet below the forward anchor light and at a horizontal distance of at least 10 feet away from it in the direction of the outlying gear.

(*h*) If a vessel when fishing becomes fast by her gear to a rock or other obstruction she shall in daytime haul down the basket required by sections (*c*), (*d*) or (*e*) and show the signal specified in Rule 11 (*c*). By night she shall show the light or lights specified in Rule 11 (*a*) or (*b*). In fog, mist, falling snow, heavy rainstorms or any other condition similarly restricting visibility, whether by day or by night, she shall sound the signal prescribed by Rule 15 (*c*) (v), which signal shall also be used, on the near approach of another vessel, in good visibility.

NOTE.—*For fog signals for fishing vessels, see Rule 15* (*c*) (*ix*).

Rule 10

(*a*) A vessel when under way shall carry at her stern a white light, so constructed that it shall show an unbroken light over an arc of the horizon of 12 points of the compass (135 degrees), so fixed as to show the light 6 points (67½ degrees) from right aft on each side of the vessel, and of such a character as to be visible at a distance of at least 2 miles. Such light shall be carried as nearly as practicable on the same level as the sidelights.

NOTE.—*For vessels engaged in towing or being towed, see Rules 3* (*b*) *and 5.*

(*b*) In a small vessel, if it is not possible on account of bad weather or other sufficient cause for this light to be fixed, an electric torch or a lighted lantern

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shall be kept at hand ready for use and shall, on the approach of an overtaking vessel, be shown in sufficient time to prevent collision.

(*c*) A seaplane on the water when under way shall carry on her tail a white light, so constructed as to show an unbroken light over an arc of the horizon of 140 degrees of the compass, so fixed as to show the light 70 degrees from right aft on each side of the seaplane, and of such a character as to be visible at a distance of at least 2 miles.

Rule 11

(*a*) A vessel under 150 feet in length, when at anchor, shall carry in the forepart of the vessel, where it can best be seen, a white light in a lantern, so constructed as to show a clear, uniform, and unbroken light visible all round the horizon at a distance of at least 2 miles.

(*b*) A vessel of 150 feet or upwards in length, when at anchor, shall carry in the forepart of the vessel, at a height of not less than 20 feet above the hull, one such light, and at or near the stern of the vessel, and at such a height that it shall be not less than 15 feet lower than the forward light, another such light. Both these lights shall be visible all round the horizon at a distance of at least 3 miles.

(*c*) Between sunrise and sunset every vessel when at anchor shall carry in the forepart of the vessel, where it can best be seen, one black ball not less than 2 feet in diameter.

(*d*) A vessel engaged in laying or in picking up a submarine cable or navigation mark, or a vessel engaged in surveying or underwater operations, when at anchor, shall carry the lights or shapes prescribed in Rule 4 (*c*) in addition to those prescribed in the appropriate preceding sections of this Rule.

(*e*) A vessel aground shall carry by night the light or lights prescribed in sections (*a*) or (*b*) and the two red lights prescribed in Rule 4 (*a*). By day she shall carry, where they can best be seen, three black balls, each not less than 2 feet in diameter, placed in a vertical line one over the other, not less than 6 feet apart.

(*f*) A seaplane on the water under 150 feet in length, when at anchor, shall carry, where it can best be seen, a white light, visible all round the horizon at a distance of at least 2 miles.

(*g*) A seaplane on the water 150 feet or upwards in length, when at anchor, shall carry, where they can best be seen, a white light forward and a white light aft, both lights visible all round the horizon at a distance of at least 3 miles ; and, in addition, if the seaplane is more than 150 feet in span, a white light on each side to indicate the maximum span, and visible, so far as practicable, all round the horizon at a distance of 1 mile.

(*h*) A seaplane aground shall carry an anchor light or lights as prescribed in sections (*f*) and (*g*), and in addition may carry two red lights in a vertical line, at least 3 feet apart, so placed as to be visible all round the horizon.

Rule 12

Every vessel or seaplane on the water may, if necessary in order to attract attention, in addition to the lights which she is by these Rules required to carry, show a flare-up light or use a detonating or other efficient sound signal that cannot be mistaken for any signal authorised elsewhere under these Rules.

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Rule 13

(*a*) Nothing in these Rules shall interfere with the operation of any special rules made by the Government of any nation with respect to additional station and signal lights for ships of war, for vessels sailing under convoy, or for seaplanes on the water; or with the exhibition of recognition signals adopted by shipowners, which have been authorised by their respective Governments and duly registered and published.

(*b*) Whenever the Government concerned shall have determined that a naval or other military vessel or waterborne seaplane of special construction or purpose cannot comply fully with the provisions of any of these Rules with respect to the number, position, range or arc of visibility of lights or shapes, without interfering with the military function of the vessel or seaplane, such vessel or seaplane shall comply with such other provisions in regard to the number, position, range or arc of visibility of lights or shapes as her Government shall have determined to be the closest possible compliance with these Rules in respect of that vessel or seaplane.

Rule 14

A vessel proceeding under sail, when also being propelled by machinery, shall carry in the day-time forward, where it can best be seen, one black conical shape, point upwards, not less than 2 feet in diameter at its base.

Rule 15

(*a*) A power-driven vessel shall be provided with an efficient whistle, sounded by steam or by some substitute for steam, so placed that the sound may not be intercepted by any obstruction, and with an efficient fog-horn, to be sounded by mechanical means, and also with an efficient bell. A sailing vessel of 20 tons or upwards shall be provided with a similar fog-horn and bell.

(*b*) All signals prescribed by this Rule for vessels under way shall be given :—

(i) by power-driven vessels on the whistle ;
(ii) by sailing vessels on the fog-horn ;
(iii) by vessels towed on the whistle or fog-horn.

(*c*) In fog, mist, falling snow, heavy rainstorms, or any other condition similarly restricting visibility, whether by day or night, the signals prescribed in this Rule shall be used as follows :—

(i) A power-driven vessel making way through the water shall sound at intervals of not more than 2 minutes a prolonged blast.
(ii) A power-driven vessel under way, but stopped and making no way through the water, shall sound at intervals of not more than 2 minutes two prolonged blasts, with an interval of about 1 second between them.
(iii) A sailing vessel under way shall sound, at intervals of not more than 1 minute, when on the starboard tack one blast, when on the port tack two blasts in succession, and when with the wind abaft the beam three blasts in succession.
(iv) A vessel when at anchor shall at intervals of not more than 1 minute ring the bell rapidly for about 5 seconds. In vessels of more than 350 feet in length the bell shall be sounded in the forepart of the vessel,

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and in addition there shall be sounded in the after part of the vessel, at intervals of not more than 1 minute for about 5 seconds, a gong or other instrument, the tone and sounding of which cannot be confused with that of the bell. Every vessel at anchor may in addition, in accordance with Rule 12, sound three blasts in succession, namely, one short, one prolonged, and one short blast, to give warning of her position and of the possibility of collision to an approaching vessel.

(v) A vessel when towing, a vessel engaged in laying or in picking up a submarine cable or navigation mark, and a vessel under way which is unable to get out of the way of an approaching vessel through being not under command or unable to manœuvre as required by these Rules shall, instead of the signals prescribed in sub-sections (i), (ii) and (iii), sound, at intervals of not more than 1 minute, three blasts in succession, namely, one prolonged blast followed by two short blasts.

(vi) A vessel towed, or, if more than one vessel is towed, only the last vessel of the tow, if manned, shall, at intervals of not more than 1 minute, sound four blasts in succession, namely, one prolonged blast followed by three short blasts. When practicable, this signal shall be made immediately after the signal made by the towing vessel.

(vii) A vessel aground shall give the signal prescribed in sub-section (iv) and shall, in addition, give three separate and distinct strokes on the bell immediately before and after each such signal.

(viii) A vessel of less than 20 tons, a rowing boat, or a seaplane on the water, shall not be obliged to give the above-mentioned signals, but if she does not, she shall make some other efficient sound signal at intervals of not more than 1 minute.

(ix) A vessel when fishing, if of 20 tons or upwards, shall at intervals of not more than 1 minute, sound a blast, such blast to be followed by ringing the bell; or she may sound, in lieu of these signals, a blast consisting of a series of several alternate notes of higher and lower pitch.

Rule 16

Speed to be moderate in fog, etc.

(*a*) Every vessel, or seaplane when taxi-ing on the water, shall, in fog, mist, falling snow, heavy rainstorms, or any other condition similarly restricting visibility, go at a moderate speed, having careful regard to the existing circumstances and conditions.

(*b*) A power-driven vessel hearing, apparently forward of her beam, the fog-signal of a vessel the position of which is not ascertained, shall, so far as the circumstances of the case admit, stop her engines, and then navigate with caution until danger of collision is over.

PART C. STEERING AND SAILING RULES

Preliminary

1. *In obeying and construing these Rules, any action taken should be positive, in ample time, and with due regard to the observance of good seamanship.*

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2. *Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist.*

3. *Mariners should bear in mind that seaplanes in the act of landing or taking-off, or operaitng under adverse weather conditions, may be unable to change their intended action at the last moment.*

Rule 17

When two sailing vessels are approaching one another, so as to involve risk of collision, one of them shall keep out of the way of the other, as follows :—

(*a*) A vessel which is running free shall keep out of the way of a vessel which is close-hauled.

(*b*) A vessel which is close-hauled on the port tack shall keep out of the way of a vessel which is close-hauled on the starboard tack.

(*c*) When both are running free, with the wind on different sides, the vessel which has the wind on the port side shall keep out of the way of the other.

(*d*) When both are running free, with the wind on the same side, the vessel which is to windward shall keep out of the way of the vessel which is to leeward.

(*e*) A vessel which has the wind aft shall keep out of the way of the other vessel.

Rule 18

(*a*) When two power-driven vessels are meeting end on, or nearly end on, so as to involve risk of collision, each shall alter her course to starboard, so that each may pass on the port side of the other. This Rule only applies to cases where vessels are meeting end on, or nearly end on, in such a manner as to involve risk of collision, and does not apply to two vessels which must, if both keep on their respective courses, pass clear of each other. The only cases to which it does apply are when each of two vessels is end on, or nearly end on, to the other ; in other words, to cases in which, by day, each vessel sees the masts of the other in a line, or nearly in a line, with her own ; and by night, to cases in which each vessel is in such a position as to see both the sidelights of the other. It does not apply, by day, to cases in which a vessel sees another ahead crossing her own course ; or by night, to cases where the red light of one vessel is opposed to the red light of the other or where the green light of one vessel is opposed to the green light of the other or where a red light without a green light or a green light without a red light is seen ahead, or where both green and red lights are seen anywhere but ahead.

(*b*) For the purposes of this Rule and Rules 19 to 29 inclusive, except Rule 20 (*b*), a seaplane on the water shall be deemed to be a vessel, and the expression " power-driven vessel " shall be construed accordingly.

Rule 19

When two power-driven vessels are crossing, so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way of the other.

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Rule 20

(*a*) When a power-driven vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, except as provided in Rules 24 and 26, the power-driven vessel shall keep out of the way of the sailing vessel.

(*b*) A seaplane on the water shall, in general, keep well clear of all vessels and avoid impeding their navigation. In circumstances, however, where risk of collision exists, she shall comply with these Rules.

Rule 21

Where by any of these Rules one of two vessels is to keep out of the way, the other shall keep her course and speed. When, from any cause, the latter vessel finds herself so close that collision cannot be avoided by the action of the giving-way vessel alone, she also shall take such action as will best aid to avert collision (see Rules 27 and 29).

Rule 22

Every vessel which is directed by these Rules to keep out of the way of another vessel shall, if the circumstances of the case admit, avoid crossing ahead of the other.

Rule 23

Every power-driven vessel which is directed by these Rules to keep out of the way of another vessel shall, on approaching her, if necessary, slacken her speed or stop or reverse.

Rule 24

(*a*) Notwithstanding anything contained in these Rules, every vessel overtaking any other shall keep out of the way of the overtaken vessel.

(*b*) Every vessel coming up with another vessel from any direction more than 2 points (22½ degrees) abaft her beam, *i.e.*, in such a position, with reference to the vessel which she is overtaking, that at night she would be unable to see either of that vessel's sidelights, shall be deemed to be an overtaking vessel; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of these Rules, or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

(*c*) If the overtaking vessel cannot determine with certainty whether she is forward of or abaft this direction from the other vessel, she shall assume that she is an overtaking vessel and keep out of the way.

Rule 25

(*a*) In a narrow channel every power-driven vessel when proceeding along the course of the channel shall, when it is safe and practicable, keep to that side of the fairway or mid-channel which lies on the starboard side of such vessel.

(*b*) Whenever a power-driven vessel is nearing a bend in a channel where a power-driven vessel approaching from the other direction cannot be seen, such vessel, when she shall have arrived within one-half mile of the bend, shall give a signal by one prolonged blast of her whistle, which signal shall be answered by a similar blast given by any approaching power-driven vessel that may be within

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hearing around the bend. Regardless of whether an approaching vessel on the farther side of the bend is heard, such bend shall be rounded with alertness and caution.

Rule 26

All vessels not engaged in fishing shall, when under way, keep out of the way of any vessels fishing with nets or lines or trawls. This Rule shall not give to any vessel engaged in fishing the right of obstructing a fairway used by vessels other than fishing vessels.

Rule 27

In obeying and construing these Rules due regard shall be had to all dangers of navigation and collision, and to any special circumstances, including the limitations of the craft involved, which may render a departure from the above Rules necessary in order to avoid immediate danger.

PART D. MISCELLANEOUS

Rule 28

(*a*) When vessels are in sight of one another, a power-driven vessel under way, in taking any course authorised or required by these Rules, shall indicate that course by the following signals on her whistle, namely :—

One short blast to mean " I am altering my course to starboard."
Two short blasts to mean " I am altering my course to port."
Three short blasts to mean " My engines are going astern."

(*b*) Whenever a power-driven vessel, which under these Rules is to keep her course and speed, is in sight of another vessel and is in doubt whether sufficient action is being taken by the other vessel to avert collision, she may indicate such doubt by giving at least five short and rapid blasts on the whistle. The giving of such a signal shall not relieve a vessel of her obligations under Rules 27 and 29 or any other Rule, or of her duty to indicate any action taken under these Rules by giving the appropriate sound signals laid down in this Rule.

(*c*) Nothing in these Rules shall interfere with the operation of any special rules made by the Government of any nation with respect to the use of additional whistle signals between ships of war or vessels sailing under convoy.

Rule 29

Nothing in these Rules shall exonerate any vessel, or the owner, master or crew thereof, from the consequences of any neglect to carry lights or signals, or of any neglect to keep a proper look-out, or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

Rule 30

Reservation of Rules for Harbours and Inland Navigation

Nothing in these Rules shall interfere with the operation of a special rule duly made by local authority relative to the navigation of any harbour, river, lake or inland water, including a reserved seaplane area.

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Rule 31

Distress Signals

When a vessel or seaplane on the water is in distress and requires assistance from other vessels or from the shore, the following shall be the signals to be used or displayed by her, either together or separately, namely :—

(*a*) A gun or other explosive signal fired at intervals of about a minute.

(*b*) A continuous sounding with any fog-signal apparatus.

(*c*) Rockets or shells, throwing red stars fired one at a time at short intervals.

(*d*) A signal made by radiotelegraphy or by any other signalling method consisting of the group • • • — — — • • • in the Morse Code.

(*e*) A signal sent by radiotelephony consisting of the spoken word " Mayday."

(*f*) The International Code Signal of distress indicated by *N.C.*

(*g*) A signal consisting of a square flag having above or below it a ball or anything resembling a ball.

(*h*) Flames on the vessel (as from a burning tar barrel, oil barrel, etc.).

(*i*) A rocket parachute flare showing a red light.

The use of any of the above signals except for the purpose of indicating that a vessel or a seaplane is in distress, and the use of any signals which may be confused with any of the above signals is prohibited.

Note.—A radio signal has been provided for use by vessels in distress for the purpose of actuating the auto-alarms of other vessels and thus securing attention to distress calls or messages. The signal consists of a series of twelve dashes, sent in 1 minute, the duration of each dash being 4 seconds, and the duration of the interval between two consecutive dashes 1 second.

Rule 32

All orders to helmsmen shall be given in the following sense : right rudder or starboard to mean " put the vessel's rudder to starboard " ; left rudder or port to mean " put the vessel's rudder to port."

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CHAPTER IV

Manœuvring in Company

THE ART of handling a ship in company, whether it be a fleet, squadron, flotilla or convoy, is mainly a question of good seamanship coupled with a regard for your consorts. In particular, the chief requirements for the efficient handling of your ship in company are :—

(i) a steady speed ;

(ii) accurate steering ;

(iii) the cultivation of a trained eye so that you can judge with accuracy relative distances, courses, speeds and rates of turning ;

(iv) a thorough knowledge of the manœuvring capabilities of your ship, and of all the orders and instructions regarding the conduct of a fleet or convoy, so that you will be able to act with accuracy, rapidity and certainty ;

(v) a due regard for your next astern and for your obligations to adjacent ships.

You will learn from the mistakes of your next ahead how best you can help your next astern. If your ship is the guide particular attention should be paid to maintaining a steady speed and course ; if the ships astern of you appear to be steering badly or are out of station it may be the fault of your own ship.

Turning Definitions

The path of a ship when turning under steady wheel is commonly termed her " turning circle," but it is more accurately described by the terms defined below and illustrated in Fig. 2.

The Advance of a ship for a given turn is the distance travelled by her pivoting-point in the direction of her original course, and it is measured from the position at which her rudder is put over. (The advance shown in Fig. 2 is for a turn of 135 degrees.)

The Transfer of a ship for a given turn is the distance travelled by her pivoting-point in a direction at right-angles to her original course. (The transfer shown in Fig. 2 is for a turn of 90 degrees.)

The Tactical Diameter is the distance that a ship has moved transversely from her original line of advance when she has turned through 180 degrees ; in other words it is the transfer for a turn of 180 degrees.

The Final Diameter is the diameter of the ship's track after it has become approximately circular.

When a ship is going ahead and puts her rudder over she will first move bodily outwards from her original line of advance and then begin to turn, and because of her inertia her pivoting-point will travel along a path which is at first one of increasing curvature, but after turning through an angle of about 90 degrees becomes approximately circular. During the turn the stem will be inside the path of the pivoting-point and the stern outside it. As a result of the ship's inertia at the beginning of the turn she should, after turning through a full circle,

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be a little ahead of and a little inside the position in which the wheel was first put over, unless of course she has been set meanwhile by wind or stream.

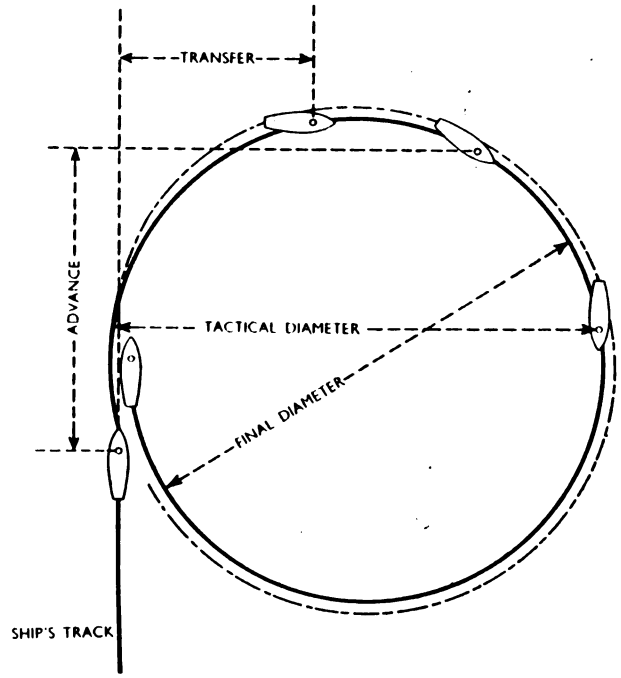

Fig. 2. A ship's turning circle

Precision when manœuvring in company and navigating in pilotage waters requires that a ship's turning capabilities should be accurately known. The necessary data under varying speeds and angles of rudder are usually found and tabulated during her initial trials. These data are, however, only a reliable indication of the ship's behaviour under conditions similar to those prevailing at the time of the trial, and the all-important factors of the direction and force of wind and sea must be taken into account whenever such data are used.

Variations in both the advance and tactical diameter, especially the former, are caused by the ship being unsteady on her course immediately before the wheel is put over. When manœuvring in confined waters, or turning in the wake of another ship, great care is therefore necessary to ensure that the ship is not swinging away from the direction towards which her course is about to be altered.

Turning Capabilities of Ships

In comparing the turning capabilities of different types of ship it can be generally said that a high-speed ship of fine form with great length in proportion to her draught, such as a cruiser or a destroyer, will have a larger turning circle than a slow, deep-draught ship of coarse form, such as a freighter. Speed does not particularly affect the turning qualities of a deep-draught ship, but the turning circle of a shallow-draft ship, such as a destroyer, will be considerably larger at high speeds than at medium or slow speeds.

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A ship will decelerate considerably during a turn under steady rudder and at constant engine revolutions, and more so under large rudder-angles than under small ones. This rate of loss of speed is greatest between the first 20 and 90 degrees of the turn, but it will continue until the ship has turned through 180 degrees, after which her speed will remain fairly constant. The rate of deceleration depends upon the speed of the ship and the angle of her rudder, and it varies greatly between different types of ship.

Very roughly, a large ship when under full rudder will have lost about a quarter of her original speed after turning through 90 degrees, and about a third after turning through 180 degrees ; whereas a small ship, such as a light cruiser or a destroyer, when under full rudder will have lost only about a quarter of her original speed after turning through 180 degrees. The figures for an average freighter are roughly the same as those for a large warship.

The correct estimation of the deceleration of a ship when turning is very important when manœuvring in company, particularly when the ship has to turn through a large angle to take station in a column.

The time a ship will take to turn through a given angle depends upon her speed and the angle of her rudder ; the faster her speed and the larger her rudder-angle the sooner will she complete the turn. The correct estimation of the time a ship will take to complete a given turn is of particular importance when manœuvring in company if she has to turn through a large angle to take station in a column.

A destroyer at full speed and under full rudder will turn through an angle of 90 degrees in about three-quarters of a minute, and through an angle of 180 degrees in about $1\frac{1}{2}$ minutes ; whereas at half speed and under 20 degrees of rudder she will take about twice as long to turn through the same angles. A cruiser at full speed and under full rudder will take a little over 1 minute to turn through an angle of 90 degrees, and a little over 2 minutes to turn through an angle of 180 degrees; at half speed and under 15 degrees of rudder she will take about $2\frac{1}{2}$ minutes and $4\frac{1}{2}$ minutes to turn through angles of 90 and 180 degrees, respectively. The average freighter will take from 7 to 8 minutes to turn through a full circle under full rudder when steaming at her normal full speed.

In multiple-screw ships, if the propeller or propellers on the side towards which the ship is turning are driven astern at the same speed as that of the propellers on the outer side, both the turning circle and the speed of the ship will be reduced considerably. The path of a ship turning under these conditions depends principally upon her type, her speed when beginning the turn, and the time taken for the reversed engines to develop the required power. When turning in this manner, though the tactical diameter is reduced, the advance will be considerably increased. The approximate tracks of a cruiser and a destroyer when turning with the inner engines reversed are shown in Fig. 3.

When turning to starboard in a single-screw ship the rate of turning will be accelerated and the turning circle reduced if her engine is put astern when the ship has begun to swing, because the screw-effect of the propeller will assist the swing of the stern to port, particularly as the ship slows down. On

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the other hand if the engine is put astern when the ship is turning to port the screw-effect of the propeller will impede the swing of the ship, and in some ships it may eventually stop the turn.

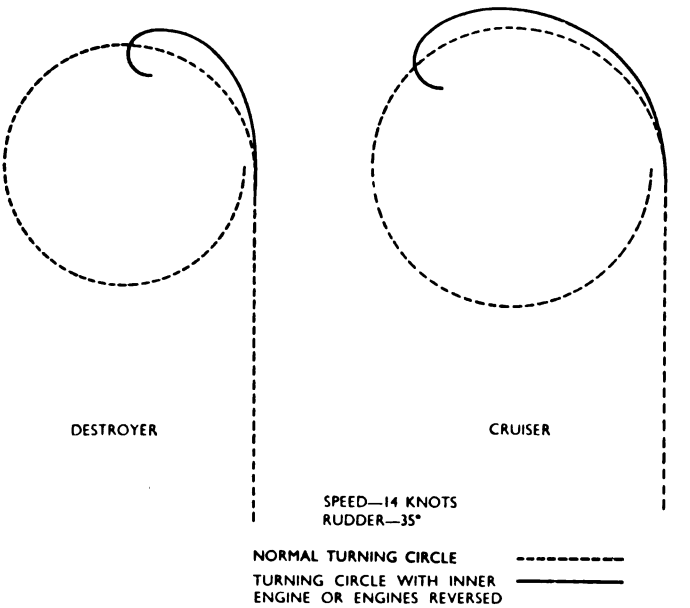

Fig. 3. Turning with the inner engine reversed—comparison between the turning circles of a cruiser and a destroyer

Tactical Rudder

When manœuvring in company, and particularly when executing equal-speed manœuvres, the tactical diameter of all ships when turning must be the same. With ships of similar class this is effected merely by ordering all ships to use a certain rudder-angle when turning, but with ships of different classes a tactical diameter corresponding to the turning powers of the most unhandy ship of the column must be ordered. In the latter event individual ships adjust their rudder-angles when turning to conform to the tactical diameter which has been ordered.

Although ships of different classes may adjust their rudder-angles to conform to a certain tactical diameter, they will not necessarily turn on similar arcs because their ratios of advance to transfer may differ widely. In such cases ships must therefore endeavour to turn on an arc similar to that of the guide by altering their rudder-angles during the turn. This may necessitate beginning a turn with a small angle of rudder and increasing it considerably later on, or *vice versa*.

Unmooring and Weighing

Ships should avoid hindering one another when unmooring. If, for example, ships of a column are lying in line with their anchors and one ship unmoors more quickly than her next ahead, she should delay shortening in on her weather cable until the latter has weighed her lee anchor.

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The object of shortening in cable before weighing is to ensure that the anchors of all ships in company break ground at about the same time after the signal to weigh is given.

It is usual to order ships to point in a certain direction immediately after weighing so that they can take station in the formation which is about to be ordered with the least amount of manœuvring; alternatively, the Senior Officer signals the course on which he intends to proceed. This order or information is usually signalled before ships begin to shorten in, so that they can be cast towards the right direction as they weigh.

In a strong outgoing tidal stream, or in a confined or congested anchorage where there may be a risk of ships under way drifting down on others at anchor, those of a unit may be ordered to weigh in succession from the rear. Ships thus weighing are usually ordered to trip their anchors when the ship astern has turned through an angle of about 45 degrees.

Turning "at rest"

When ships under way but stopped are ordered to turn together they should turn without moving either ahead or astern and at the same time preserve their compass bearings and distances from the guide. The rate of turning should normally be regulated to that of the slowest ship, but in circumstances such as a crowded tidal river it may be necessary for each ship to turn as quickly as she can.

Leaving Harbour

When leaving an open anchorage ships may be ordered to turn together to a certain course and then proceed at a certain speed; they then go ahead together, preserving compass bearings and distances from the guide, until another formation is ordered by signal. Alternatively, a formation, course and speed may be ordered without first pointing ship; ships then go ahead together, turn to the course ordered and take up the required formation as they leave harbour.

Inverting the column.—If the Senior Officer has led his ships into harbour and then, when the time comes to leave, wants to lead them out again, it will often be necessary to invert the column. In this case, when the ships have

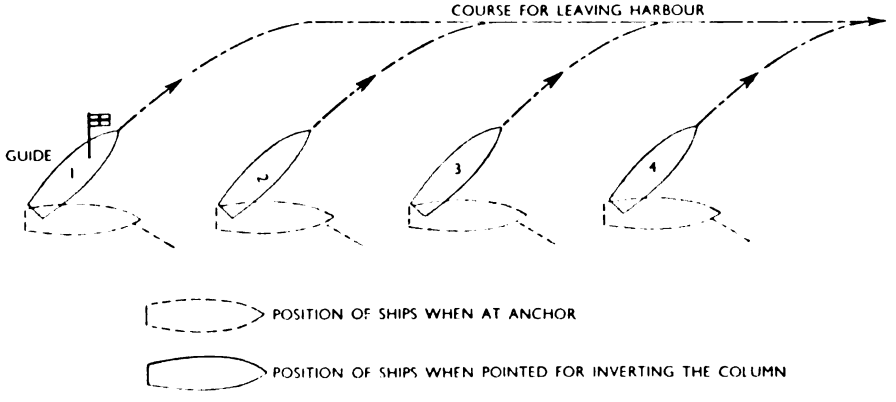

Fig. 4. Inverting the column when leaving harbour

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weighed they are pointed in a direction about 20 degrees from the intended course for leaving harbour. The guide then goes ahead at the speed ordered and turns on to the course for leaving harbour, which will probably be the reciprocal of the course on which the squadron anchored ; the remaining ships then follow the guide in succession from the rear and form into column astern of her (see Fig. 4).

The following is a good rule for determining when to go ahead so that your ship will be the correct distance from the guide when you take station astern of her :—

> Add the distance of your ship from the guide when at rest to her distance from the guide when in station ; the time taken for a ship to cover this distance at the speed ordered is the interval between the time the guide goes ahead and the time you should go ahead. Suppose, for example, that a squadron intends to invert the column and proceed to sea at 10 knots with a distance between ships of 3 cables ; yours is to be the second ship in the column and the guide is lying 3 cables astern of you. You should go ahead 3 minutes and 36 seconds after the guide, this being the time taken to cover 6 cables at a speed of 10 knots.

The foregoing rule holds good only for ships of the same class. As a rough rule for ships of approximately the same displacement and type, you should go ahead at the speed ordered when your next ahead is about 100 yards astern on a parallel course.

If you are dropping astern of station when forming up, you should immediately order a large increase in speed, because it is easy to reduce speed if you find you are too close, but difficult to regain lost ground. On the other hand you should not go ahead too early or too quickly because this will make it more difficult for ships astern of you to take up their station.

Taking Station in the Column

Taking station astern of another ship from astern.—For this manœuvre you must decide when to reduce speed so that the way of your ship will carry her exactly into station. The following figures afford a rough indication of the allowances which should be made when reducing speed to take station in a column ahead :—

aircraft carriers ... 100 yards per knot ;
cruisers ... 50 yards per knot ;
destroyers ... 40 yards per knot.

If, for example, a cruiser, which is astern of the fleet and steaming at 20 knots, is ordered to rejoin and take station 3 cables astern of another ship proceeding at 12 knots, she should reduce speed to 12 knots when she is 5 cables astern of the other ship [600 yards + (8 × 50 yards) = 1,000 yards].

Taking station between two ships in the column from astern.—In this manœuvre you should never attempt to cut in close ahead of the ship which is to be your next astern, and you should not reduce to the speed of the column until your stern is well clear of her bows. If you should run up too close to your next ahead a small amount of rudder should keep you clear of her. It is advisable to alter to the course which the column is steering when about one cable clear of your next ahead, and then ease in to the line gradually and reduce speed. The ship astern should allow you plenty of room for this manœuvre.

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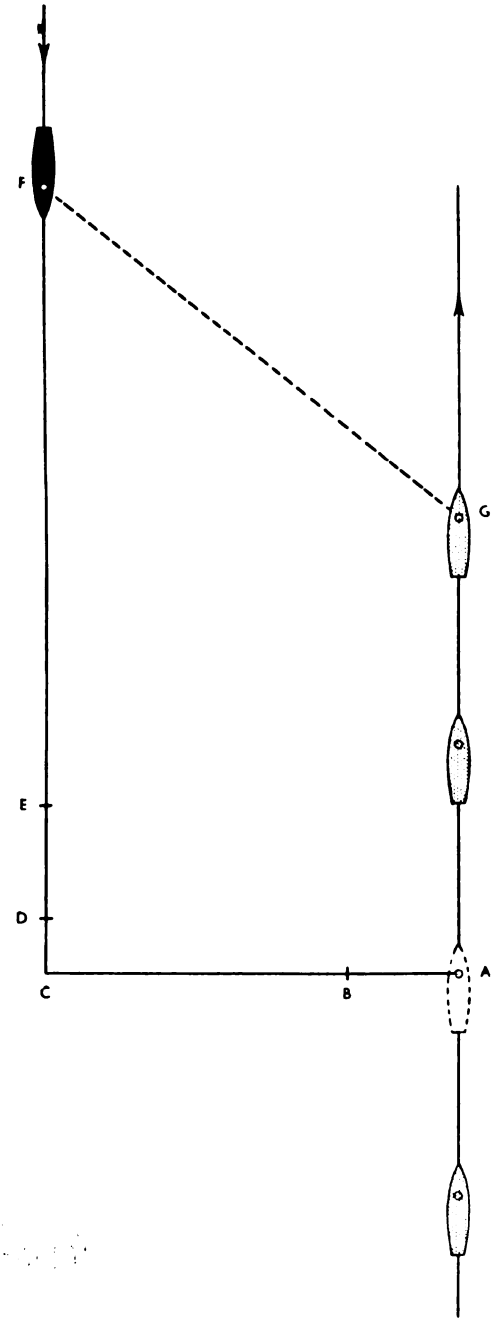

Fig. 5. Taking station in the column from right ahead

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Taking station between two ships in the column from right ahead.—This is not such a difficult manœuvre as might be imagined, if you have an accurate knowledge of the turning capabilities of your ship. If possible you should approach on a course from ahead which is the exact reciprocal of that which the column is steering, and at a speed exceeding that of the column by an amount equal to your loss of speed when turning. The distance between your course and that of the column should be equal to your tactical diameter plus a safety-margin of from 100 to 300 yards, depending upon the type of ship and the state of the sea.

Fig. 5 illustrates the method by plotting of determining the exact moment when to put the wheel over.

A represents the intended position of the ship in the column ;
AB represents the safety-distance ;
BC represents the tactical diameter ;
CD represents the advance for a turn of 180 degrees ;
DE represents the distance the ship drops astern due to loss of speed during the turn ;
EF represents the distance the column will have run during a turn of 180 degrees ;
F represents the position at which the wheel should be put over ; EFG and FG being respectively the bearing and distance of the guide at this moment.

If during the last stage of the turn, it is seen that the ship will fetch up at a safe distance from the column the wheel can then be eased and the ship edged in to her station.

Taking Station between two Ships in the column from broad on the bow.—If a ship broad on the bow is ordered to take station in the column she would lose a lot of time if she attempted the manœuvre from a reciprocal course, and so the usual method is for her to steer for a position ahead of the column from which she can turn into it. This manœuvre is more difficult than that of turning from a reciprocal course, and it requires better judgment of relative speeds and distances, particularly at high speeds. In some circumstances it may be prudent to make an initial turn well clear of the line so that the final approach is within 60 degrees of the course of the column.

A rough method of finding the position for putting the wheel over and the course to steer for that position are shown in Fig. 6.

First estimate roughly the position in which to put the wheel over and then find the course to steer for this position. Then estimate the advance and transfer for the required turn. Next plot the distances as shown in Fig. 6 where :—

A represents the intended position in the column ;
AB represents the safety-distance ;
BC represents the transfer ;
CD represents the advance ;
DE represents the distance the ship drops astern owing to loss of speed during the turn ;
EF represents the distance the column will have run during the turn ;

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F represents the position at which the wheel should be put over ; if the course to steer for this position differs largely from the rough estimate the advance and transfer for the turn should be re-estimated.

Taking-up and Changing Station

A new station must be taken up immediately and by the shortest route clear of other ships. If the new station is at some distance from you, or ahead, you should proceed at your maximum available speed if alone, and at one knot less than the maximum if in company, unless a specific stationing speed has been ordered. If ground has to be lost you must decide how best to lose it, whether by proceeding directly to your new station, reducing speed, zig-zagging broadly or by turning through 360 degrees.

First the course to the new station should be roughly estimated and the ship be turned on to it while you find the exact course, either by plotting or by the Battenberg course indicator. If you are in the line and the required alteration of course is small you should first haul out well clear of the line and then turn on to the new course. When estimating the course to the new station, beginners usually overestimate the amount of alteration required because they forget to make an allowance for the distance covered by the guide while their ship is taking station. If, for example, you are two cables astern of the guide and you are ordered to take station two cables abeam of her, and if your maximum speed is two knots greater than the speed of the guide, the necessary alteration of course will be only about one point.

Station-keeping

Accuracy in keeping station is most important, and you should endeavour to maintain your correct station with the smallest possible alterations of speed and rudder. This entails watching the ship you are keeping station on very closely and making small alterations as soon as the ship begins to get out of station. An alteration in speed of a quarter or half a knot at a time, and an alteration of rudder of five degrees to either side, should suffice for the average ship in calm weather. If, however, you find yourself badly out of station you should take resolute action to regain station ; if, for example, you are one cable out of station you would not be justified in taking, say, ten minutes to creep back. Large ships steaming at slow speed, and all ships steaming into steep head seas, will require larger alterations of speed and rudder than are normally sufficient. Destroyers and other light craft are more affected than heavier ships by the wind, sea and the wash of other ships ahead of them, and they will usually require larger but briefer alterations of speed.

Guides of columns keep station on the guide of the fleet or convoy, and ships in column keep station on the guides of their respective columns. You may not always be able to see your guide and you may then have to keep station on the nearest ship between yourself and the guide, but you should always endeavour to maintain station on the guide unless it entails getting dangerously close to an adjacent ship.

Station in a line of ships should be kept at the distance ordered, measured from foremast to foremast, or in ships without a foremast, from navigating

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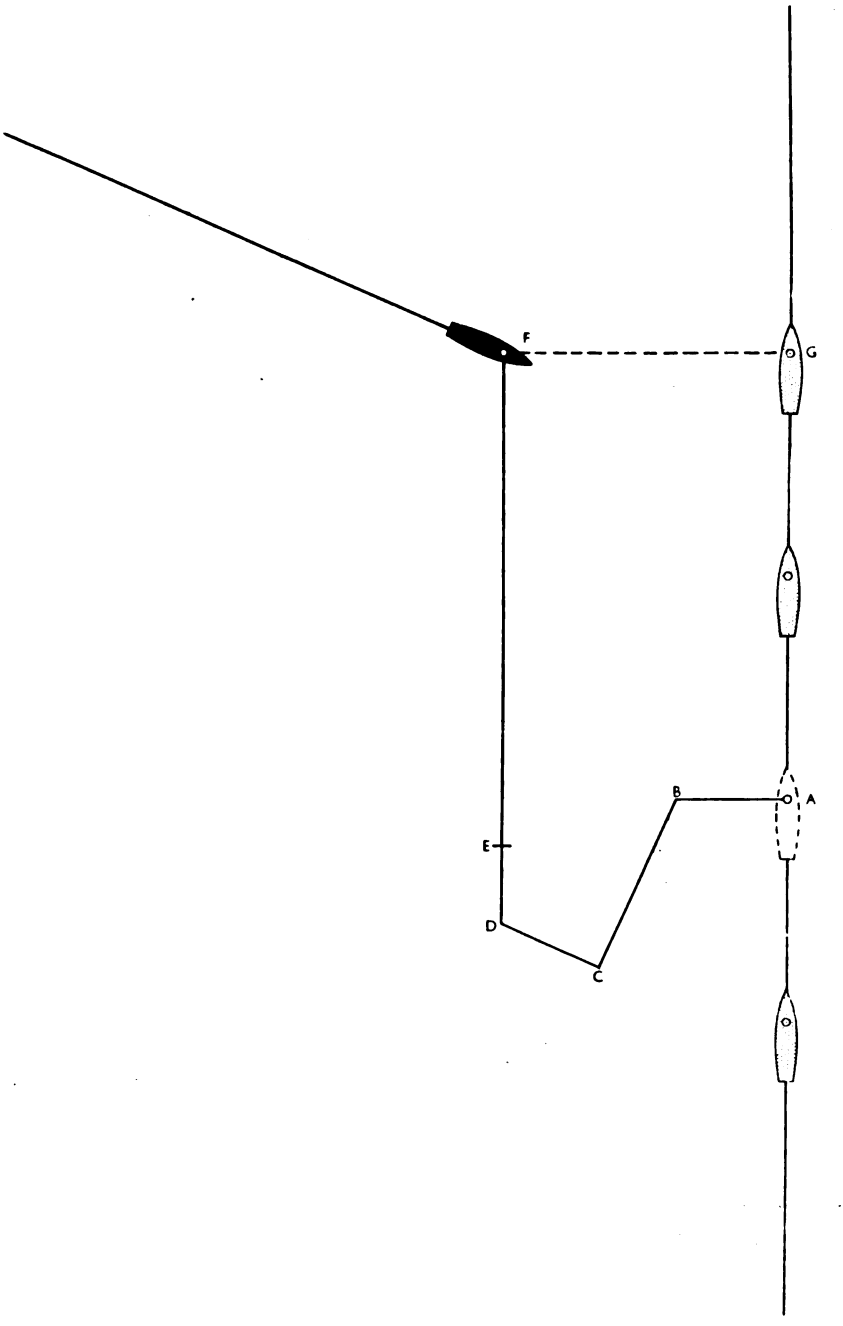

Fig. 6. Taking station in the column from broad on the bow

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bridge to navigating bridge. When in column every endeavour should be made never to fall astern of station, and when in line abreast you should never get ahead of station.

If you are out of station for distance you will find the " six-knot-minute rule " useful for determining the required alteration for speed and the time required for regaining your station. This rule formulates that to change the station of a ship by one cable her speed must be altered from that of the column by the following amounts :—

½ knot for 12 minutes ;
1 knot for 6 minutes ;
2 knots for 3 minutes ;
3 knots for 2 minutes ;
4 knots for 1½ minutes ;
6 knots for 1 minute.

It will be noted that the product of the amount by which speed is altered, and the period for which the alteration is made, is always six.

Aids to station-keeping are the compass for bearing, and distance-meters, rangefinders or the sextant for distance. When measuring distance by the vertical angle between some object such as the main-truck of the ship on which you are keeping station and her waterline, it is her waterline immediately below the object which must be observed ; if, as when in column, the waterline at this point cannot be seen, some mark known to be in line with it must be used instead. It is better to use the foremast of a ship as a ranging mark than the mainmast because the former is near the ship's pivoting-point and so will more correctly indicate the position of the ship when she is turning.

Keeping station in column.—If your ship is the guide you should ensure that her speed is kept constant by warning the engine-room, and pay particular attention to steering both a steady course and the correct course. In this connection it is worth noting that if the guide of a column steaming at 18 knots steers three degrees off the course ordered she will open or close an adjacent column at the rate of about one cable in six minutes.

If your ship is neither the guide nor the second ship in the column always try to keep station on the guide (or if you cannot see her, on the nearest visible ship to her) rather than on your next ahead. If each ship in the column follows this rule individual errors in station-keeping will not appreciably affect the rear ships of the column. Often, however, the guide and the ships next astern of her are masked by your next ahead, on whom you will then have to keep station.

You should learn to judge distance accurately by eye, or by comparing a mark in your own ship with one in the ship on which you are keeping station ; you need then use your distance-meter only occasionally as a check on your judgment. At night when steaming without lights you can judge the distance of your ship from your next ahead quite accurately by comparing the position of the white water directly under her stern with some readily visible mark fixed to your jackstaff or forestay. Another method of judging your distance from your next ahead by night is to note the space occupied by her silhouette in the field of your binoculars when your ship is in station ; then, if her silhouette is larger than normal you will be ahead of station, and if smaller you will be astern of station.

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In a small ship and in a heavy following sea great care must be taken not to run up unexpectedly on your next ahead. If you get too close to your next ahead you should haul out to one side or the other. If the wind is to one side it is usually best to haul out to windward, but if your ship is carrying rudder it is best to ease the wheel and let the ship turn in the direction she wishes to go. If there is another column abeam of yours and you have to haul out well clear of the line, should a man fall overboard for example, you should turn away from the adjacent column. If your next ahead hauls out of the line for a man overboard you should immediately turn a small amount in the opposite direction so that you will be well placed to lower a boat close to the man.

If when keeping close station you find it difficult to maintain the speed of the column, or if you wish to save fuel, keep your ship just outside the wake of your next ahead. Experience has shown, particularly with small ships and at high speeds, that the wash of a ship appreciably retards the speed of a ship close astern of her.

When proceeding along a narrow channel in a strong beam wind, or when a cross-current is running, due allowance should always be made for leeway or the set of the current, and you should steer so as to *make good a course down the centre of the channel* instead of following directly in the wake of the guide, otherwise the line will sag to leeward so that the rear ships may be in danger of grounding on that side of the channel. Ships in column may be ordered to maintain compass bearings and distances from the guide, but the guide is not obliged to make such an order because captains are always individually responsible for the safe navigation of their own ships.

In low visibility if a ship is astern of you your fog buoy should be ready for streaming at four-fifths of the standard distance between ships in column. To keep station on the fog buoy of your next ahead you should keep it close to and abreast your bows. It is a good plan to place two lookouts in the eyes of the ship, the sole duty of one being to watch the fog buoy and point to its position should you lose sight of it, particularly if it is hidden by the flare of your bows.

Turning in succession in column.—If your ship is the guide you should always use the same amount of rudder when turning, and ensure when completing a turn that you do not overshoot the new course, by even one degree. It is, in fact, preferable to stop the swing of the ship almost entirely about three degrees before reaching the new course, and then allow the ship to swing very slowly to the course and no further. The moment at which to ease the wheel amidships and the amount of opposite rudder required to meet the swing and so steady the ship on the new course vary greatly with the type and class of ship.

When a turn in succession is ordered each ship should endeavour to steer as steady a course as possible directly astern of the guide. It is most important to ensure that each ship is steady immediately before her wheel is put over, because a yaw at this stage, especially if it be outward, will certainly ruin the manœuvre.

As soon as your next ahead puts his wheel over you should steady by compass on his bridge and not on his stern. The moment at which he puts his wheel over will be indicated by a "kick" in his wake. In small ships

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steaming at high speed, however, it is better to steady by compass on the course of the unit or on a course which will bring your ship into the correct position to begin the turn.

There are several methods of judging the exact moment at which to put your wheel over. One is to put the wheel over when your stem has reached a certain position in relation to the kick in the wake of your next ahead; the position varies with the type and class of ship and the speed of the column, and it can only be found by experience. Another method is to put the wheel over when a certain interval of time, commensurate with the distance between ships and the speed of the column, has elapsed after the guide or your next ahead put his wheel over; this is an accurate method if there is some indication of the exact moment at which a ship puts her wheel over. Yet another, and perhaps the best method, is to put your wheel over when the bridge of the guide reaches a predetermined bearing relative to your own bridge; this bearing depends on the position of your ship in the column, and tables can be made out for the different positions a ship may occupy in a column.

When turning it should be remembered that the pivoting-point of your ship should travel over the same arc as that of your next ahead so that your stem should travel inside this arc and your stern outside it. You should therefore keep your stem well inside the " white water " of the wake of your next ahead.

If you have put your wheel over too late your ship will turn outside the wake of your next ahead and fall astern of station; more rudder will then have to be applied, which in turn will result in a further loss of speed and distance. In this event you must therefore order a bold increase of speed immediately you see that your ship is starting to turn outside the wake. If despite this you find your ship still turning outside the wake you should not try to cut in, but should complete the turn and steady your ship outside the wake of your next ahead before edging in to your proper station; if you try to cut in during the turn you will greatly increase the difficulties of ships astern of you.

Turning too early, and consequently inside the wake, is a fault which can very easily be corrected in its early stages by easing the wheel and reducing speed. The sooner this is done the better, otherwise, in a large turn, you will soon find yourself uncomfortably close to your next ahead.

Keeping station on a bearing.—When stationed on a bearing and distance from the guide, plot the relative positions and tracks of the guide and your ship on a mooring board or a Battenberg course indicator, otherwise you may be confused when deciding what action to take to maintain or regain station. It should be remembered that if you alter your course *or* speed both your bearing *and* distance will be affected by an amount depending on the *relative bearing* of your ship from the guide. When on the bow or quarter an alteration of course or speed will be equally effective in correcting both the bearing and distance; the finer the relative bearing, however, the more will distance be affected by speed and bearing by course, and conversely, the broader the relative bearing the more will distance be affected by course and bearing by speed (see Fig. 7).

When keeping station on a bearing it should not be necessary to alter course more than a few degrees, or speed more than a couple of knots, to maintain station.

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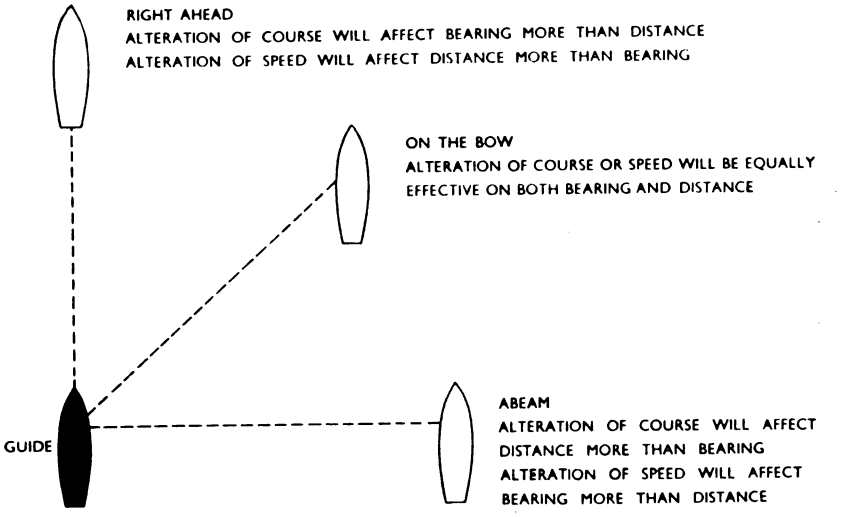
RIGHT AHEAD
ALTERATION OF COURSE WILL AFFECT BEARING MORE THAN DISTANCE
ALTERATION OF SPEED WILL AFFECT DISTANCE MORE THAN BEARING
ON THE BOW
ALTERATION OF COURSE OR SPEED WILL BE EQUALLY EFFECTIVE ON BOTH BEARING AND DISTANCE
GUIDE
ABEAM
ALTERATION OF COURSE WILL AFFECT DISTANCE MORE THAN BEARING
ALTERATION OF SPEED WILL AFFECT BEARING MORE THAN DISTANCE

Fig. 7. Keeping station on a bearing—effects of altering course or speed

Keeping station when anchoring in column or on a bearing.—Maintaining accurate station when approaching an anchorage is of paramount importance. The ideal to aim at is to be in station and steady on the guide at the moment of stopping engines. If you are out of station the ships astern of you will be affected less by your error if you are ahead of station and dropping back than if you are astern of station and overhauling. In the former case you will be carrying less way than the guide, and a few more revolutions after he has stopped will not unfavourably affect ships astern of you; but in the latter case you will be carrying too much way when the guide stops and you will then overrun and be unable to correct it without affecting the ships astern of you.

Keeping a Plot

When manœuvring in company at any time a plot showing the relative courses and positions of your own and other ships is of great value; when manœuvring in a large fleet, or in low visibility, or at night, and particularly in wartime when ships are darkened, a plot is essential. Without a plot under such conditions you may well be confused and lose station or lose touch with other ships, and you will then be a danger to your consorts.

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CHAPTER V

Handling Ships in Narrow Waters

THE WAY in which a vessel behaves when being manœuvred depends upon her means of propulsion, her steering, the shape of her hull, the disposition of her superstructures, her loading and her trim, the weather, and the depth of water. The handling of one vessel may therefore differ greatly from that of another, but certain fundamental principles apply to all. Experience in handling different types of vessels in different circumstances is naturally of great value, but it is not essential if the ship-handler has a good knowledge of the principles of handling ships and of seamanship in general.

A knowledge of the handling qualities and any peculiarities of a particular ship should be gained as soon as is practicable after taking command of her, and this is best done when the ship is at sea on a calm day, by dropping a mark such as a box or a Dan-buoy in an area clear of traffic, and practising for an hour or so the more common manœuvres.

In this chapter the more common problems of handling ships in narrow waters are described for the benefit of those seamen who lack experience of these matters.

MANŒUVRING IN GENERAL

Means of Propulsion

A ship may be fitted with a single screw, or with twin, triple, or quadruple screws.

In a single-screw ship the propeller is almost invariably right-handed; that is, when the ship is driven ahead the propeller revolves in a clockwise direction when viewed from astern.

Almost all twin-screw and quadruple-screw ships have out-turning propellers, right-handed on the starboard side and left-handed on the port side. In quadruple-screw warships both propellers on each side are normally always worked ahead or astern together. In quadruple-screw merchant ships, however, it is usual for the outer propellers only of each pair to be used when manœuvring, and as a rule the two inner propellers of turbine-driven merchant ships cannot be driven astern. Triple-screw ships are usually manœuvred by their outer propellers, the centre propeller being used to accentuate turns and movements ahead or astern.

Means of Steering

When the rudder is turned to a given angle with the fore-and-aft line its effect on the ship depends primarily on the speed at which it is being dragged against the water. The movement of the water in relation to the rudder may be caused either by the ship's speed or by the slipstream to or from the propeller, or a combination of the two. The turning power of the rudder thus depends on the size of the rudder, its shape and type, its position in relation to the propellers, and the underwater form of the hull.

It is obvious that the larger the rudder the greater will be its steering effect.

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The two principal types of rudder are the " hinged " and the " balanced " rudder (Fig. 8). The former is hinged by pintles and gudgeons on the sternpost or rudderpost of the ship and rotates about an axis at its foremost edge. The latter is pivoted on a rudderpost or hung from the rudderhead so that about one third of its area is before the pivot.

The hinged rudder is fitted on the older types of single-screw merchant ships, but most modern ships, whether single-screw or multiple-screw, are fitted with the balanced rudder.

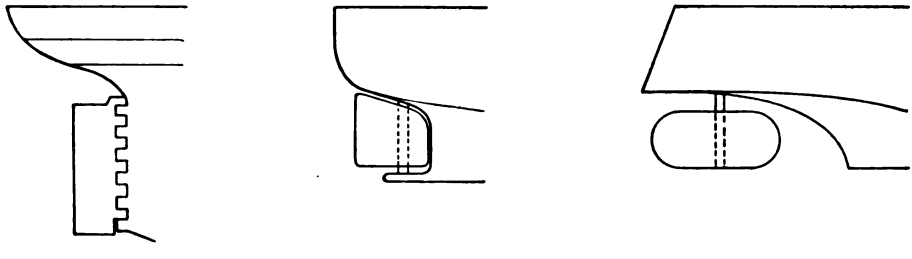

Fig. 8. The two principal types of rudder

The position of the rudder in relation to the propeller or propellers is most important, particularly when the ship is being manœuvred at rest, or ahead at low speeds. The slipstream from an ahead-turning propeller is of spiral form, and if the rudder is placed directly astern of the propeller the slipstream will impinge on both sides of the rudder and so increase its turning effect even though the ship is at rest or only moving ahead slowly. Thus the rudder of a single-screw ship will be effective from the moment the propeller starts to turn ahead, and the faster the propeller turns the greater will be the turning effect of the rudder.

In a twin-screw ship fitted with a single rudder the slipstreams from the propellers will pass on each side of the rudder almost without impinging upon it, and so the rudder will have little or no power to turn the ship until she has gathered sufficient headway to provide an effective flow of water against the rudder. Thus a twin-screw ship when stopped or moving slowly ahead relies on her propellers to provide the turning power. To increase their turning power when stopped or moving slowly ahead, some twin-screw ships are fitted with twin rudders placed as near the slipstreams of the propellers as is practicable.

When a propeller is turning astern it has little or no effect on the rudder, and so when going astern in both single- and multiple-screw ships the rudder will have little effect until the ship has gathered appreciable sternway.

Propeller action

Screw-effect.—In addition to the fore-and-aft thrust produced by a revolving propeller there is an athwartships thrust called " screw-effect ", which is caused by the propeller blades meeting less resistance from the water during the upper half of their travel than in the lower half. The screw-effect of a right-handed propeller tends to swing the stern of a ship to starboard when the propeller is turning ahead and to port when it is turning astern. When a ship has gathered sufficient headway her frictional wake (which is in effect a surface

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current caused by the belt of water dragged along by the underwater part of the ship through friction) increases the resistance of the water to the propeller blades during the upper half of their travel, and so reduces or eliminates their screw-effect. When a ship is moving astern, however, the propellers encounter no frictional wake, and in a single-screw ship the screw-effect can be countered only by the effect of her rudder, which in turn depends on the speed of the ship.

When both propellers of a twin-screw ship are turning at the same speed ahead or astern the screw-effect of one is balanced by that of the other, but if one propeller is driven at a different speed from the other, or if one is driven ahead and the other astern, they can be used with great effect for turning the ship. In fact, when turning a twin-screw ship which is stopped or moving slowly the screw-effect of a side propeller is greater than the turning moment owing to its thrust, and its combined thrust-moment and screw-effect are greater than the effect of the rudder. A high-powered and easily handled ship, such as a destroyer, can be effectively manœuvred in narrow waters by her propellers alone.

In a single-screw ship the screw-effect of her propeller considerably influences the way in which she is manœuvred at low speeds ahead or astern, and when stopped. When starting to move ahead the first movements of a right-handed propeller kick the ship's stern to starboard, but as she gathers headway this effect decreases as the frictional wake increases, and eventually the effect of the latter predominates and may even start to swing the stern slightly to port. When beginning to move astern the first movements of the propeller will kick the stern to port, and because the propeller will not then encounter the frictional wake the stern will continue to swing to port until checked by the rudder. The rudder, however, will have little effect until the ship has gathered considerable sternway, and in some ships this swing cannot be stopped unless the propeller is stopped.

Vibration.—When a propeller is driving a ship ahead it sets up a current (called the " propeller-race ") by drawing water towards itself from ahead, churning it into spiral form, and forcing it astern into the wake, and for the propeller to work efficiently the flow of water towards it must be unrestricted. If when the ship is going ahead her engine is reversed, the propeller will not work efficiently until the speed of the ship has been considerably reduced, because it cannot draw water from aft at a sufficient rate ; the propeller will therefore be working in a partial vacuum and so will tend to race, which causes considerable vibration in the hull of the ship. Vibration may also be caused when the ship is moving fast in shallow water, because the flow of water to the propeller is then restricted by the closeness of the sea bed.

Rudder action

When the rudder of a ship making way is put over she will turn about a pivoting point, the position of which depends on whether the ship is moving ahead or astern, and also on the type of ship and her trim. When going astern the pivoting point of all ships is right aft. When going ahead, however, the position of the pivoting point varies with the type of ship ; in most warships it lies at a point roughly between one-sixth and one-third of the ship's length from the stem, and in most merchant ships it lies amidships or a little farther forward. If the ship is trimmed by the head or the stern the pivoting point will shift towards the deeper end.

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The outward bodily movement of the ship at the start of a turn, and the swing of her stern outwards as she turns about her pivoting point, should be borne in mind when manœuvring in narrow waters. The lateral movement of the stern outwards from the original line of advance will, however, probably not be more than twice the beam of the ship.

Draught, trim and list all affect the turning qualities of a ship. A small decrease in a ship's draught will slightly increase her turning circle, but a large decrease of draught will very considerably decrease her turning circle; for example, a freighter will turn in a much smaller circle when in ballast than when deeply laden. The normal turning circle of a ship will be increased if she is trimmed by the stern, and decreased if trimmed by the head. If a ship has a list she will turn more readily away from the side to which she is listing and her turning circle will be decreased; if she turns towards that side her turning circle will be increased.

Steering when going Astern

A multiple-screw ship should steer easily when going astern once she has gathered sternway and provided there is little or no wind, the wheel being put to starboard to swing her stern to starboard, and *vice versa*. If the ship is being turned by "backing and filling" she must be kept swinging in the required direction throughout the manœuvre; when taking off headway before gathering sternway the best moment to reverse the wheel is when the headway has been reduced to between one and two knots, because then sufficient water is being drawn in from astern on to the rudder by the propellers for the rudder to have the same effect as if the ship actually had sternway.

A single-screw ship, however, is difficult to steer when going astern. If she has a right-handed propeller her stern can easily be swung to port when going astern because her rudder and the screw-effect of her propeller will both act in the same direction. It will be difficult, however, to swing her stern to starboard, particularly at low speeds, because the screw-effect will act in the opposite direction to the rudder until the ship has gathered sufficient sternway for the effect of the rudder to predominate, and even then the swing to starboard will be very sluggish. To swing the stern to starboard it is usually necessary first to gather sternway with the rudder hard-a-starboard and then stop the engine; if she has sufficient sternway her stern will then swing to starboard. For these reasons, when there is little or no wind, a right-handed single-screw ship is always turned short by "backing and filling", with her head swinging to starboard and her stern swinging to port.

Effects of Loading

The difference between the displacement, draught, trim and waterplane area of a warship and of a passenger liner, when fully laden and when lightly laden, is not particularly great, and their manœuvring capabilities are therefore much the same under all conditions of loading. In a freighter, however, these differences are very considerable, and her manœuvring powers will vary largely with her loading; generally speaking, a freighter handles best when she is half or two-thirds laden.

When deeply laden a freighter will have a much larger turning circle than when lightly laden, and she will be more sluggish in answering her rudder; she will also be sluggish in gathering steerage way and require considerable

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power or force to stop her once she has gathered headway. The wind, however, will have very little effect on her unless it is very strong.

When " flying light " a freighter will be lively, answer her rudder readily, have a much smaller turning circle than when heavily laden, will turn readily on her anchor, and her way can be easily checked by her hawsers or anchors and cables. Her propeller, however, may be only half immersed and her powers of acceleration and deceleration will be correspondingly low. Also, she will tend to skid sideways when under wheel, which will complicate her handling in narrow or tortuous channels, and because of her light draught she will be much influenced by any wind.

Effect of Trim

Trim has a considerable effect on a ship's manœuvring qualities. When she is trimmed by the stern her turning circle is usually increased, and although she will steer well she is difficult to turn into the wind. When she is trimmed by the head her turning circle is likely to be decreased ; she will not so readily answer her wheel, but once she has started to swing it is difficult to check her.

A ship usually handles best when she is trimmed slightly by the stern.

Effects of Shallow Water

When a ship is steaming in shallow water, especially if at high speed, the water between the sea bed and her bottom is displaced by the frictional drag of her hull, and as this water cannot be rapidly replaced her propellers and rudder are working in a partial vacuum which causes the ship to become directionally unstable. The ship will therefore take longer to obey her rudder when altering course once a yaw has developed. The depth of water in relation to the draught of the ship at which such unsteady steering begins varies with the ship's speed, but experiment has shown that a ship going at her normal speed may begin to experience unsteady steering when she enters water of a lesser depth than one-and-a-half times her draught, and as the water becomes still shallower her steering will become increasingly unsteady. A ship drawing 14 feet, for example, may begin to steer unsteadily in 3½ fathoms of water. The most obvious signs of such conditions are excessive propeller vibration and the piling up of a large wave directly astern of the ship. The steering is also affected when the ship is moving slowly in shallow water, and this should be borne in mind when berthing in shallow harbours.

Another effect of shallow water is to reduce the speed of the ship and increase her effective draught, and usually the bigger the ship and the higher her speed the greater will be this effect. Put briefly, this is due to changes in wave formation caused by the passage of the ship from deep to shallow water. A ship moving at moderate or high speed builds up a wave under her bows and another at her stern. When entering shallow water the water displaced by the passage of the ship cannot be rapidly replaced, with the result that the waves at her bows and stern increase in size ; as their size increases they offer more resistance to the passage of the ship and so reduce her speed. At the same time the ship's stern wave builds up and produces a deep trough under the quarters of the ship into which her stern sinks and so increases the ship's effective draught aft.

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Handling of Main Engines

Speed

Most multiple-screw ships have sufficient manœuvrability to enable them to carry out all manœuvres with the engines turning at half or slow speed, ahead or astern, full speed being reserved for emergencies.

When manœuvring, the slowest speed consistent with full control of the ship should always be used and it should be noted that one excessive engine movement will probably breed others, and may lead to loss of control in narrow waters.

In single-screw ships, however, the screw-effect of the propeller in certain manœuvres predominates over the effect of the rudder, particularly at low speeds, and for this reason certain manœuvres of single-screw ships are better carried out with the engines at full speed ahead or astern so as to take full advantage of any screw-effect. In such ships the full speed used for manœuvring should be well within the capacity of her engines so that a good margin is available for emergencies.

Co-operation

The need for perfect co-operation and sympathetic understanding between bridge and engine-room cannot be too strongly emphasised, particularly when the ship is manœuvring. Those in control on the bridge and in the engine-room should thoroughly understand each other's difficulties and the material limitations imposed on each.

In turbine-driven ships it takes appreciably longer to alter the movement of the engines (*e.g.*, from " Stop " to " Slow ahead " or *vice versa*) than in ships driven by reciprocating engines, and in large ships the time lag may be as much as 10 seconds or more from the time the order is received in the engine-room. This unavoidable lag must be taken into account on the bridge when a " kick " ahead or astern is required during a manœuvre.

The astern power of turbine-driven ships is always considerably less than the ahead power, because the propellers are driven astern by a separate set of turbines which are less powerful than the main ahead turbines. Also, the astern turbines are not economical in the use of steam and therefore high revolutions astern cannot be maintained for an indefinite period because the high expenditure of steam involved will soon result in a loss of steam pressure in the boilers.

Sudden large reductions in speed (unless the excess steam is expended by going astern) may well seriously damage the boilers, and in this respect the time : reduction factor which can safely be accepted should not be exceeded except in emergency. Sudden large increases of speed, though not liable to damage the boilers, cannot be provided immediately except for a short period in an emergency because they would require more steam than the boilers could produce and result in an unavoidable loss of pressure, and eventually an actual reduction of speed.

When a twin-screw ship is manœuvred in harbour the engines must be " balanced " when obeying orders such as " Half ahead (or astern) both engines" or " Half ahead port. Half astern starboard " (by balanced is meant that both engines must be moved at the speed ordered at the same rate of acceleration or deceleration). If care is not taken thus to balance the engines when obeying

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such orders a moment will be set up between the propellers causing the ship to develop a sudden and unexpected swing.

Effects of a Wind

The manner in which a ship will react to the force of the wind depends upon the position of her pivoting point (which, in turn, depends upon the shape of her hull below water, her trim and her movement through the water), and also upon her freeboard, the shape of her hull above water, the shape and disposition of her superstructures, and her movement in relation to the direction of the wind.

The extent to which a ship will react to a wind depends upon the strength of the wind and the loading of the ship; the effect of the wind on a deeply laden ship will be much less than on one which is lightly laden.

When stopped, a ship will lie more or less broadside on to the wind, and when losing way her bows will tend to fall off from, or come up into the wind, depending on its direction in relation to the ship, until she lies broadside on to the wind.

When going astern the bows will always tend to pay off from the wind and the stern to come up into the wind, because the ship's pivoting point is then right aft and all her windage area is before her pivoting point. In a strong wind it may not be possible to check this tendency; it is sometimes useful, however, as it can be used to great advantage when executing certain manœuvres.

When going ahead the tendency of the bows of the ship to fall off from, or come up into, the wind depends chiefly on the disposition of her windage area before and abaft her pivoting point, and on the direction of the wind. Ships of different types will therefore react differently to a wind when going ahead, but any tendencies will be more marked at low speeds than at high speeds.

Gaining and Losing Speed

A knowledge of the rate at which a ship gains or loses speed in different circumstances is invaluable when anchoring and when manœuvring in confined waters or in company. These rates depend chiefly on the displacement of the ship, her condition of loading, her draught, her horsepower, the size of her propellers, and the depth of water; the corresponding rates for one ship will therefore differ largely from those of another, also the rates for a particular ship may change considerably with her condition of loading.

In calm weather an aircraft carrier will reach a speed of 10 knots from rest in about 8 minutes, in which time she will have covered a distance of about 11 cables; if her engines are stopped when she is steaming at 10 knots she will lose her way in about 8½ minutes over a distance of about 6 cables; if her engines are reversed to half speed astern when steaming at 10 knots she will lose her way in about 4 minutes over a distance of about 4 cables.

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The rough figures for a cruiser and a destroyer are as follows :—

	TIME IN MINUTES	DISTANCE IN CABLES
CRUISER		
To attain 14 knots from rest	5	8½
To lose way after stopping engines at 14 knots	10	8
To lose way after reversing engines to half speed astern at 14 knots	5	3½
DESTROYER		
To attain 20 knots from rest	3	6
To lose way after stopping engines at 20 knots	2	4
To lose way after reversing engines to half speed astern at 20 knots	1½	2

A 10-knot freighter of some 8,000 tons displacement will take from 10 to 12 minutes to attain her normal full speed from rest, and will cover a distance of from 10 to 12 cables in this time; if when steaming at her normal full speed her engines are reversed to full speed astern, she will probably bring up in a distance of about half a mile.

These data for a selected range of speeds are usually obtained when the ship carries out her initial trials, and they are then entered in the Ship's Book and in the Ship's Navigational Data Book.

A rough rule for estimating the rate at which a warship gains or loses speed when changing from one speed to another, and the method of applying the rule is given on page 56.

Loss of speed due to foul bottom.—If a ship lies for long in harbour, particularly in a tropical harbour, her bottom will be fouled by weeds, barnacles and other marine parasites or growths, and her speed will be reduced accordingly. The extent of this fouling depends largely on the locality of the harbour, the fouling in some harbours being much worse than in others. Steaming at high speeds and lying at anchor in rivers will reduce the amount of fouling.

No definite figures can be given for loss of speed due to the fouling of a ship's bottom because so much depends on the route the ship follows and the time she spends at her ports of call, and the only way of determining how much to allow for a particular ship is frequently to check her actual speed with what her speed should be for the revolutions ordered.

Use of Berthing Hawsers

Intelligent handling of berthing hawsers can add greatly to the ease and speed with which a ship is berthed alongside, and for this the effect of heaving

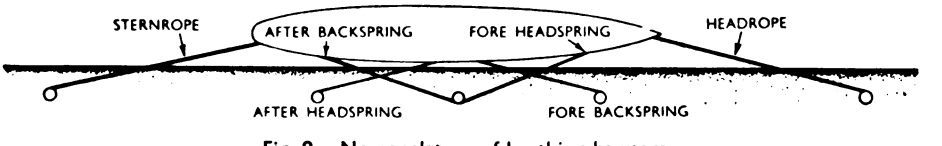

Fig. 9. Nomenclature of berthing hawsers

in any particular hawser under any given circumstances must be known. (The standard nomenclature of berthing hawsers used in the Royal Navy is shown in Fig. 9).

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It is assumed in the first place that the ship is stopped and lying square with the jetty. If then a fore breastrope is made fast and hove in the bows will obviously be moved in towards the jetty, but because the ship will also turn about her pivoting point her stern will move away from the jetty at the same time. This movement of the stern will not be as great as that of the bows because the pivoting point is not rigidly held, and so the ship will also move bodily towards the jetty.

If, on the other hand, an after breastrope had also been made fast and held taut, the ship would have pivoted about her stern as the fore breastrope was hove in, and she would have been moved in bodily but at an angle with the jetty.

If both fore and after breastropes are hove in together, the ship will be breasted in squarely with the jetty. If either of these hawsers is led ahead or astern it will act as a spring, and as it is hove in the ship will be moved ahead or astern at the same time that she is moved towards the jetty.

It is now assumed that the ship has a certain amount of headway when the fore breastrope is made fast. As the ship moves ahead this hawser will grow aft, and, as it tautens, her head will be bowsed in towards the jetty. The momentum of the ship acting through her centre of gravity will increase this swing because the ship will then pivot about her bows and her stern will swing out.

If instead of the fore breastrope an after breastrope had been made fast the result would have been very different. The pivoting of the ship would then have been well abaft her centre of gravity and her forward momentum acting through her centre of gravity, combined with the pull of the hawser on her quarter, would have resulted in the ship being moved in bodily towards the jetty and very nearly parallel with it.

Summarised, the difference is that with a ship moving ahead a fore headspring bowses the bows in sharply and swings the stern out, whereas an after headspring will scarcely turn the ship; in both cases, however, the ship is moved bodily in towards the jetty. With the ship moving astern the result is, of course, reversed.

Should the spring be led from the ship abreast her centre of gravity, she will move in bodily without being cast in either direction, and her alignment with the jetty can then be altered by using rudder.

In practice, of course, both the rudder and propeller are used when a ship is being worked alongside on a spring, and the best position for the spring is then not abreast the centre of gravity but abreast a point roughly halfway between it and the bows or stern. With a hawser secured in this manner maximum advantage can be taken of the spring's ability both to cast the ship and to move her bodily, while still using her rudder and propeller.

When slipping from a jetty the usual method is to go ahead on the fore headspring and so cast the stern out sufficiently far from the jetty for the ship to go astern clear of any obstacles astern of her. When used in this manner a spring may well part unless it is tautened gradually. The best method of tautening it is to cast off all hawsers except the spring and the headrope; then, by heaving in on the headrope, not only will the spring be tautened, but the bows will be bowsed gently in to the jetty and the stern cast slightly out.

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Judgment of Speed and Distance

Before executing any harbour manœuvre it is essential to think out how you intend to do it and what rudder and engine movements will be required. Your plan must be sufficiently flexible to allow for modifications to meet such unforeseen circumstances as a sudden change of weather or movements of nearby shipping. Once you have made your plan and given due consideration to your ship's behaviour under the prevailing weather conditions, its successful execution will depend on good judgment of speed and distance, and an accurate forecast of the effects of any tidal stream or wind.

When there is no wind or tidal stream, speed can be judged by watching some object floating alongside, provided it is not affected by the wash of the propellers or the movement of the ship. In a wind or tidal stream, however, the movement of the ship must be estimated by watching transits on shore because it is the speed over the ground that is required. Bearing in mind that high speeds are dangerous except in special circumstances, such as a strong cross current or beam wind, it is better to watch a nearby object in relation to a distant one than to watch two objects in the middle distance, because the relative positions of the latter would alter slowly and thus tend to make you underestimate your speed.

Judgment of distance is much affected by the observer's height above the water; from a high bridge objects appear to be nearer than they really are, and from a low bridge they appear farther away. Usually, the farther forward the bridge the more accurately can distances ahead be estimated.

When approaching a berth the direction of the ship's head in relation to anything ahead, a jetty for example, is best estimated by standing amidships on the bridge so that the stem serves as a mark for the fore-and-aft line. If it is necessary to con the ship from the wing of the bridge, some object in the ship lying directly ahead, such as a bollard, should be taken as a mark in preference to the stem.

MANŒUVRING IN HARBOUR WITHOUT TUGS

The handling of a single-screw ship is so affected by her propeller that she will sometimes have to be manœuvred in a different way from that for a multiple-screw ship. Where such is the case the method for a right-handed single-screw ship is described here first and then the method for a twin-screw ship fitted with out-turning propellers.

Each manœuvre is described first as it should be carried out in calm weather, and then in a wind. The effects of a tidal stream on manœuvring are described in a later section of this chapter.

Anchoring, Riding at Anchor, and Weighing

Anchoring

When choosing a berth in which to anchor sufficient room must be allowed for the ship to swing without fouling others in the anchorage. The usual allowance for the radius of a berth at single anchor is the amount of cable to be veered, plus the length of the ship, plus half a cable or a cable.

It should be borne in mind that except in a strong wind or tidal stream a

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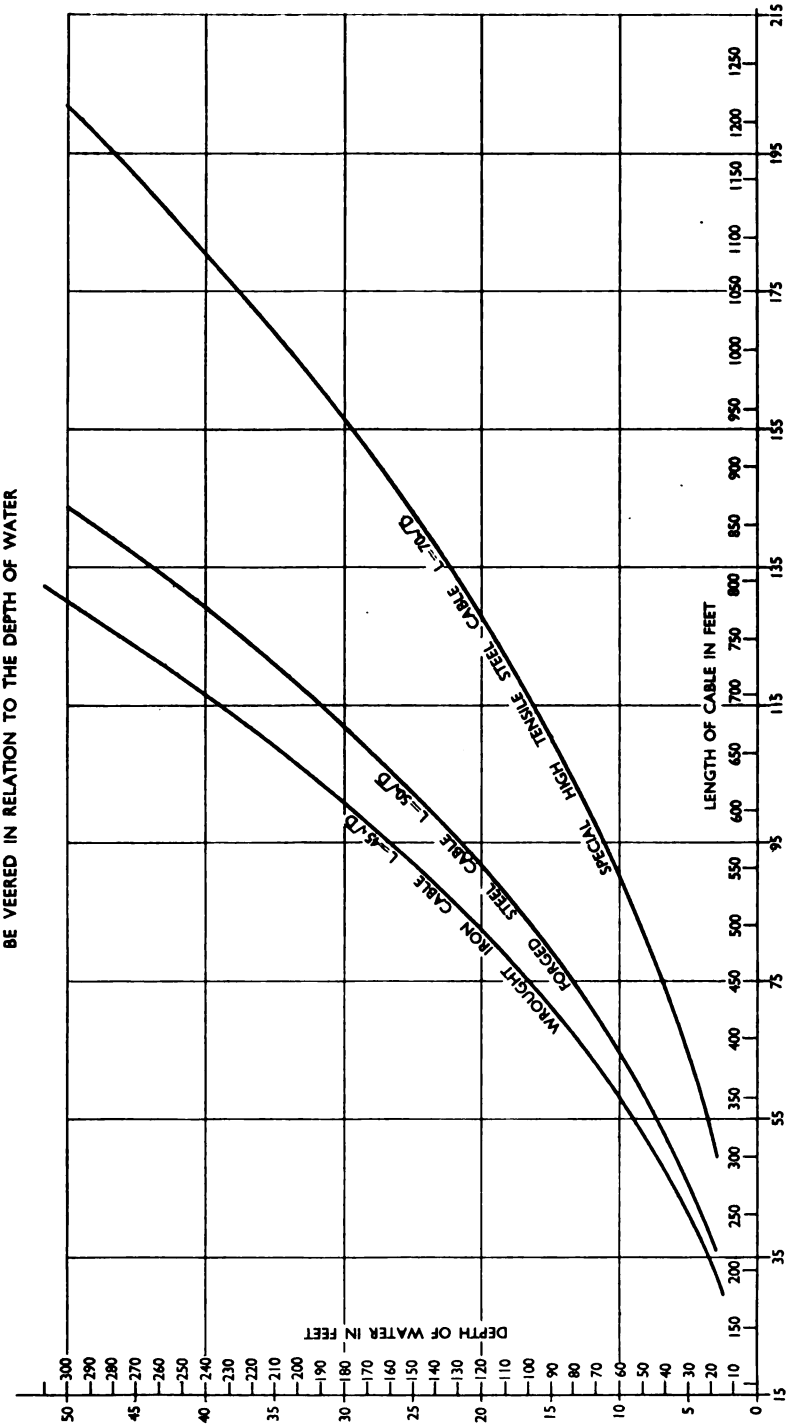
GRAPH SHOWING THE MINIMUM LENGTH OF CABLE TO BE VEERED IN RELATION TO THE DEPTH OF WATER
DEPTH OF WATER IN FATHOMS
DEPTH OF WATER IN FEET
LENGTH OF CABLE IN FEET
LENGTH OF CABLE IN FATHOMS
WROUGHT IRON CABLE L=5.1D
FORGED STEEL CABLE L=5D
SPECIAL HIGH TENSILE STEEL CABLE L=7D
NOTE :—IN FORMULA FOR EACH CURVE. L AND D. ARE IN FEET

Fig. 10.

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ship may be riding to the bight of her cable lying on the bottom, so when anchoring near another ship it should not be assumed that she is riding at the full scope of her cable.

The amount of cable to be veered depends upon many factors, but it should always be enough to ensure that it imparts a horizontal pull to the anchor at all times, otherwise the anchor will lose much of its holding power and will probably drag ; a pull in a direction only 15 degrees above the horizontal will reduce by more than a half the holding power of the anchor. The old rule for determining the amount of cable to be veered in any circumstances was to multiply the depth of water by a factor ranging from 4 to 8 and depending on the type of cable being used. This rough rule, however, was inaccurate and in deep water impracticable, because it did not take into account that the factor should be reduced with an increase in the depth of water. A graph showing the minimum amount of cable to be veered to ensure that a sufficient length lies on the bottom next the anchor is given in Fig. 10. It is based on the formula $L = F \sqrt{D}$, where L is the length of cable to be veered, D is the depth of water, and F is a factor depending on the type of the cable, *i.e.*, wrought iron, forged steel, or special high-tensile steel. It is emphasised that the graph gives the minimum length of cable to be veered in calm weather and in a tidal stream of five knots, and that more should be veered in high winds or very strong tidal streams. Provided that sufficient cable is veered to impart a horizontal pull on the anchor the veering of any more cable will not greatly increase the holding power of the ground tackle, because while an anchor in reasonably good holding ground will hold from about $3\frac{1}{2}$ to 7 times its weight according to its type, cable will offer a resistance of only about three-quarters of its weight. Cable does, however, act as a spring and therefore as a shock absorber, and so the greater the length of cable veered the less will be the possibility of imparting to the anchor sudden loads due to pitching, yawing or squalls.

In anchorages where hills or mountains descend steeply to the shore, in creeks, lochs or fjords, for example, a particularly sharp lookout on the weather should be kept, because in such localities exceptionally strong, squally winds are liable to occur with little or no warning. In such anchorages it is prudent to furl awnings and hoist boats at nightfall, and to set an anchor watch.

The extent to which the speed of a ship should be reduced before anchoring depends upon her type, the strength of the wind and stream, and whether she is to be stopped or have headway on her when her anchor is let go. When alone in a clear anchorage it is usual to let go the anchor with the ship stopped and about to gather sternway, but when anchoring together in formation, or anchoring very exactly in a berth, it is usual for ships to let go their anchors with headway on. If, for example, a light fleet carrier is to let go her anchor with headway on, her speed is reduced to 12 knots when she is two miles from her anchor berth, to eight knots when she is one mile away, her engines are stopped when she is five cables away, and put to slow astern (40 revolutions) when she is half a cable away. In a frigate approaching her berth at 12 knots, if her anchor is to be let go when she is stopped and about to gather sternway, her speed is reduced to nine knots when she is five cables from her berth, to five knots (slow ahead) when she is two cables away, her engines are stopped when she is one cable away, and put half speed astern (revolutions for nine

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knots) when she is half a cable away ; the anchor is let go as the propeller wash reaches abreast the bridge when the ship is just about to gather sternway, and the engines are put to slow astern when the propeller wash is about 20 yards ahead of the bows. In both the above examples it is assumed that there is no wind or tidal stream. It is useful to remember when stopping a ship with her engines that as the wash of the astern-going propellers reaches amidships the ship will usually have lost her headway.

When anchoring with headway on, the ship's speed over the ground should never be more than four to five knots when the anchor is let go, and thereafter it should be reduced progressively until the ship is brought to rest just as she gets her cable. Having too much way on when the ship comes to, or too little way on while laying out the cable must be avoided ; the first may part or strain the cable or unbed the anchor, and the second will unduly prolong the operation or prevent the cable being laid out correctly. Bringing the ship correctly to rest after anchoring depends on the circumstances and on experience, and requires an accurate estimation of the ship's speed over the ground throughout the manœuvre ; common aids to the estimation of speed are the bottom log if the ship is going ahead, the speed at which the cable is running out, bearings or transits of nearby stationary objects, and chips of wood or balls of paper thrown overboard and clear of the propeller wash.

Ensuring that the anchor is given a chance to embed itself, and subsequently laying the cable out straight along the bottom without straining it or unbedding the anchor are important. When anchoring in less than 15 fathoms of water an amount of cable equal to twice the depth of water should first be allowed to run out freely to enable the anchor to embed itself. Thereafter the brake of the cableholder or windlass should be applied so that the cable is kept growing at an angle of about 30 degrees with the vertical. The brake should not be applied fiercely or the cable be snubbed ; a quarter of a turn should suffice, so that if the cable tautens unduly it can render and so reduce the strain on itself. When a stationary cable tautens and then slackens it is a sign that the ship has come to rest.

When anchoring in deep water the anchor should be lowered to the bottom and not let go because there is then a chance of the anchor being fractured as it hits the bottom or the links of the first shackle of cable being fractured as they pile up on themselves. In from 20 to 30 fathoms of water the cable should be veered slowly on the brake until the anchor reaches the bottom, and in over 30 fathoms the cable should be veered under power to ensure it is under full control.

When anchoring in a wind it is usual to approach the berth head to wind, as no allowance need then be made for leeway. In any but strong winds such an approach is, however, by no means obligatory because the drift to leeward can easily be allowed for if a bearing or transit ahead is watched. The weather anchor should always be used, otherwise the cable will foul the stem of the ship as she drifts to leeward after letting go her anchor, and if the approach has been made head to wind the ship's head is cast about ten degrees to one side or the other just before letting go the anchor to ensure she will pay off in the required direction.

When anchoring in a strong wind or a gale it is advisable to let go the anchor with the ship stopped and with her head cast no further off the wind than is

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necessary to ensure that she pays off in the required direction, because as soon as the ship starts drifting her head will pay off very rapidly. The more the ship's head pays off the greater is the windage area she offers and the faster will she drift. To give the anchor a chance of embedding itself and holding, more than the normal amount of cable should be allowed at first to run out freely, and the cable should then be braked carefully to bring the ship's head back towards the wind without dragging the anchor, this being assisted if necessary by a kick ahead on the engines. When her head has been brought back to about 20 degrees from the wind more cable can be veered.

If, however, it is expected that the ship will have to ride out a strong and prolonged gale, it would be best to let go both anchors spread apart so that the angle between their cables will be about 20 degrees when the ship is riding to them. To do this the approach should be made with the wind a little before the beam, and the weather anchor should be let go first with headway on the ship. The ship should be brought to rest and the lee anchor be let go when the ship has covered a distance equal to a little less than one third of the amount of cable to be veered. As the ship drifts leeward the cables should be veered and middled.

When anchoring or mooring in a tidal stream it is usual to stem the stream unless the wind is particularly strong. Except in strong tidal streams a ship can let go her anchor with headway on, but while her cable is laid out she should be kept head to stream, and the order " Finished with main engines " should never be given until she is riding to her cable and it is certain that her anchor is holding. In a strong tidal stream, however, the anchor should be let go with the ship stopped, and the cable should be laid out carefully as the ship drifts downstream but with her head kept pointing upstream.

If it is not practicable to stem a tidal stream when anchoring, the cable should be laid athwart the stream so that as the ship swings to the stream the bight of her cable dragging over the bottom will help to bring the ship gently to her anchor.

When anchoring head to stream in a beam wind it is best to let go the lee anchor, because when eventually the ship comes to her cable her bows will swing towards the wind, and her cable will then grow clear, and broad on the lee bow.

Anchoring or mooring with a following tidal stream of more than half a knot is not recommended, because a very heavy strain will then be imposed on the cable, particularly when the ship is swinging athwart the stream. When mooring in a strong tidal stream it is best to make a dropping moor because this lessens the risk of dragging the upstream anchor.

In a strong river current a ship should be moored with two anchors spanned athwart the current, in the manner recommended for riding out a gale, to prevent her yawing. In a tidal stream yawing can be checked to a certain extent by use of the rudder.

The following method of anchoring has been used successfully by H.M. surveying vessels in the Pacific when anchoring off atolls or coral islands rising steeply from the bottom in very deep water. It should only be attempted when there is no wind, or when the wind is blowing off-shore or off the reef.

While a good lookout is kept from the masthead for shoals and coral heads,

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the approach is made very slowly with the anchor veered to between 8 and 17 fathoms and held by the brake. Depths of 8 fathoms are usually found very close to the reef, and at depths of more than 17 fathoms the reef usually falls away too steeply for the anchor to obtain a hold. When the anchor is felt to bite, the ship goes astern slowly, so as not to dislodge the anchor, and at the same time cable is paid out slackly. Another anchor is then lowered at open-hawse to assist in preventing the ship from dragging. Should the wind shift there is no danger of getting a foul-hawse, because the anchors must be weighed and the ship stand out to sea if there is any chance of her swinging onto the reef. To prevent the stern of the vessel from drifting onto the reef in a flat calm, an expendable weight made up of scrap-iron, sinkers or firebars is lowered over the stern to a depth of about 30 fathoms on a stout manila rope tailed with about five fathoms of wire rope or chain. As the stern drifts shorewards the weight will foul the coral bottom and hold the stern clear.

Riding-out a Gale

If suddenly overtaken by a gale when at single anchor the first precaution to take is to veer a sufficient amount of cable to ensure that the extra stresses of yawing or pitching are absorbed as much as possible by the spring in the cable, and that the cable is exerting a horizontal pull on the anchor. At the same time steam should be raised, an anchor watch set, and the second anchor prepared for letting go.

Little can be done to prevent pitching except perhaps to trim the ship by the head. Sudden stresses caused by pitching can to a certain extent be damped down by shackling a heavy weight such as a sinker or kedge anchor to the cable before veering it ; this weight, just lying on the bottom, will increase the spring or shock-absorbing qualities of the cable, and ensure that the pull of the cable on the bower anchor is horizontal.

Even in a very steady gale a ship will not always point dead into the wind, and yawing is started by the wind blowing on one side of the ship when she is not heading into wind so causing her to sail through the water. The combined actions of the wind, and the pull of her cable will make the ship yaw first to one side and then to the other, her stem tracing a figure-of-eight path as shown in Fig. 11. From this illustration it will be seen that the ship presents a large windage area throughout the greater part of the yaw, thus increasing the strain on the cable. Furthermore an extra heavy load is produced as the ship first rides up on her cable and then falls back on the slack cable at the extremities of

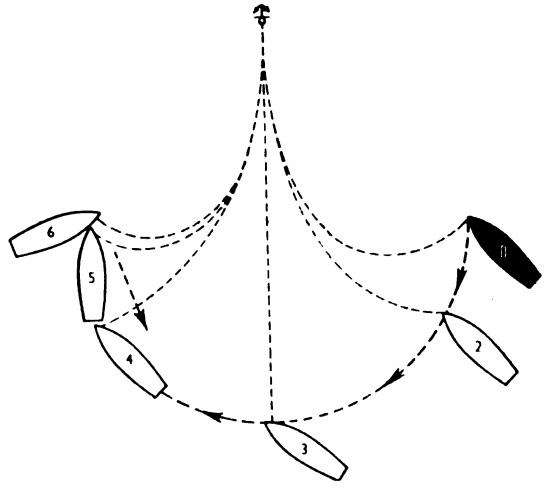

Fig. 11. Successive stages of the yaw of a ship at single anchor

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her yaw. Ships with their superstructure disposed forward and with a deeper draught aft than forward are more prone to yawing than ships with their superstructures amidships or aft and trimmed on an even keel. Yawing to any marked degree may well cause the anchor to drag, and it should therefore be prevented when practicable. Opinion differs among experienced seamen on the best method to check a yaw. Some let go the second anchor underfoot at the middle of the yaw and hold it at short stay, so that the pull of the anchor as it drags along the bottom helps to check the yaw; others let it go when the ship reaches the limit of her yaw to that side which is farthest from the first anchor, they then veer both cables until the second anchor has sufficient cable to enable it to hold, and the ship then rides to both her anchors. If circumstances allow, however, and if there is a probability of dragging, it is best to steam ahead to a position close abreast the first anchor, drop the second anchor, and then ride to both cables veered an equal amount.

If a gale warning is received when in an anchorage where the holding ground is none too good, where there is little sea-room to leeward, or where other ships are berthed nearby, if circumstances permit it is best to weigh and anchor again with both anchors in a clear berth well upwind, but if this is impracticable proceeding to sea should be considered.

If warning of a typhoon or a hurricane is received when the ship is in harbour, the decision whether to ride it out or put to sea depends largely on the type of ship, the nature of the holding ground or strength of the moorings, what sea-room is available, and the proximity of the storm and its probable course. If it is decided to put to sea the decision must be made in good time so that the ship may make a good offing and so have plenty of sea-room to leeward when the storm overtakes her. It is often inadvisable to put to sea when the storm arrives, because when the ship leaves the shelter of the harbour she may meet mountainous and confused seas set up by the backwash from the coast.

Steaming to the cable to ease the strain on it has been done with success, but it is not recommended unless suitable landmarks are available for fixing the ship's position. If landmarks are obscured the ship may find herself dangerously out of position, and if she falls back on her cable after overriding it the sudden strain may well unbed her anchor. Ships secured to buoys, however, have successfully ridden out a typhoon by steaming to their bridles, thus easing the strain on both bridle and mooring. The position of the buoy being fixed and well in sight from the bridge, there should be no danger of over-riding the bridles or getting out of position, but care must be taken to keep a steady strain on the bridles and not to jerk them.

Provided there is plenty of sea-room to leeward and the ship is not moving into any dangers or into very deep water, dragging in itself does not always call for drastic emergency action such as slipping the cables. Ships anchored in wide bays or open anchorages have dragged slowly and steadily for several days at the rate of about a mile a day without harm while riding out a prolonged gale. Dragging should, however, be avoided because it imposes heavy loads on the cables as the ship rides up and then falls back on them each time she is brought to.

Emergency Measures

When dragging onto a lee shore or nearby shipping, drastic action must be taken, the nature of such action depending on the circumstances.

If circumstances allow the best action is to weigh and either to anchor again

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in a better position well upwind and in better holding ground, or to proceed to sea. When weighing in these circumstances the anchor may begin to come home well before it is weighed and the ship to drift rapidly to leeward; the engines should then be put ahead boldly and the ship steamed to windward, towing her anchor along the bottom until she is in a position to weigh it, and then to anchor again or proceed to sea. This has been done successfully even when both anchors have been let go.

When dragging at single anchor beam on to a strong gale it may be difficult to get the ship head to wind to steam up to the anchor to weigh it. In these circumstances, if sea-room allows, the engines should be put boldly ahead and the ship steamed round her anchor. The drag of the anchor on her bow should bring the ship up into the wind when she can steam beyond the position of her anchor and then drift down on it while weighing. In ships with high bows and their superstructure disposed well forward this method may prove impracticable, and the only alternative is to attempt the same manœuvre but by going astern instead of ahead, relying on the tendency of all ships to bore up stern to wind when moving astern.

Any of the above methods may be impracticable because of lack of time or sea-room to leeward, or because of nearby shipping or other hazards, and in these circumstances it is best to slip the cable, or cables, and proceed to sea. It should be borne in mind, however, that if both cables are slipped the ship will subsequently have no means of anchoring. When slipping a cable the end should be buoyed to enable it and the anchor subsequently to be recovered. Such cable should be buoyed with a wire rope buoy pendant of sufficient strength to recover the cable.

Weighing

Apart from weighing anchor in a gale, this is a very simple manœuvre about which little need be said. As the cable is hove in the ship will gather a certain amount of way towards her anchor which will help to break the anchor out of its bed, particularly when the bottom is muddy and the ship's capstan none too powerful. Single-screw ships usually require considerable room to turn, and in confined and crowded anchorages in calm conditions it is therefore often best first to heave in cable to short stay, until there is just sufficient scope of cable out to prevent the anchor coming home, and then to steam round the cable to the required direction as described on page 80.

When weighing in company warships usually first heave in to short stay before weighing to ensure that their anchors are broken out simultaneously when the order to weigh is given.

If there is a wind it is of no advantage to steam round the cable, because even if the ship were headed in the required direction by this means she would swing back head to wind in the final stage when the anchor was being weighed. It is important, however, to ensure that when the anchor is aweigh the bows will not pay off in the opposite direction to that in which you wish to turn. This is done by first allowing the bows to pay off slightly in the wrong direction while shortening in the cable, so that in the final stage of weighing the bows are given a very decided cast in the required direction.

When heaving in cable to weigh anchor the cable may grow athwart the stem and so be subjected to a bad nip. When this occurs "Vast heaving" should be ordered until the bows swing towards the anchor and the cable grows

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clear again. If this is not done an unduly heavy strain will be imposed on the links and joining shackles of the cable when they pass across the stem, which may result in the cable parting or being severely strained.

Turning short

A single-screw ship in calm weather and with sufficient room in which to manœuvre, is best turned to starboard with headway on her, and to port with sternway, as shown in Fig. 12. In any preliminary manœuvring it should be borne in mind that the ship will turn fastest in position (3) after her engines are put ahead, because then the rudder with the wash of the ahead-turning propeller against it will exert its full effect and assist the swing of the stern to port.

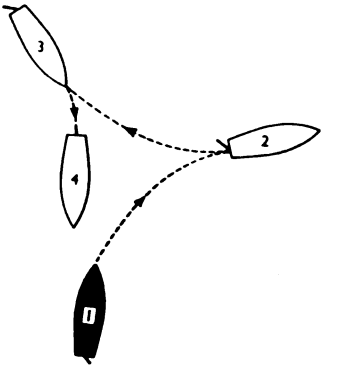

Fig. 12. Turning short in a right-handed single-screw ship

To turn short in a right-handed single-screw ship which is stopped, you should proceed as follows (see Fig. 12) :—

(i) Put on starboard rudder and go ahead on the engine. The wash from the propeller acting on the rudder will then swing the stern to port, and as way is gathered the swing will increase more and more rapidly. Continue this movement until the ship has as much headway as is safe, and has run ahead as far as room allows.

(ii) Then reverse the engine to full astern and put the rudder hard-a-port. The screw-effect will continue to swing the stern to port, and as sternway is gathered this swing will be further increased by the rudder.

(iii) Now put the engine to full ahead and the rudder hard-a-starboard.

(iv) Continue to " back and fill " in this manner until the turn is completed.

If there is room for the ship to move ahead and astern for some distance, and at a moderate speed, it is possible to turn to port by a similar series of manœuvres. The turn will be much slower and require more sea-room, however, because when the engine is working astern the screw-effect of the propeller will tend to reduce the swing and possibly start one in the wrong direction, whatever the movement of the ship through the water.

In a wind much depends on the direction of the wind in relation to the ship throughout the manœuvre, and in single-screw ships the following points should always be borne in mind :—

(i) Whenever possible, advantage should be taken of the marked tendency of the bows to fall off the wind when the ship is moving astern ;

(ii) when stopped or losing way the ship will always tend to turn broadside on to the wind ;

(iii) when making a stern-board the rudder will have little or no effect unless the propeller is stopped or the ship has gathered considerable sternway ;

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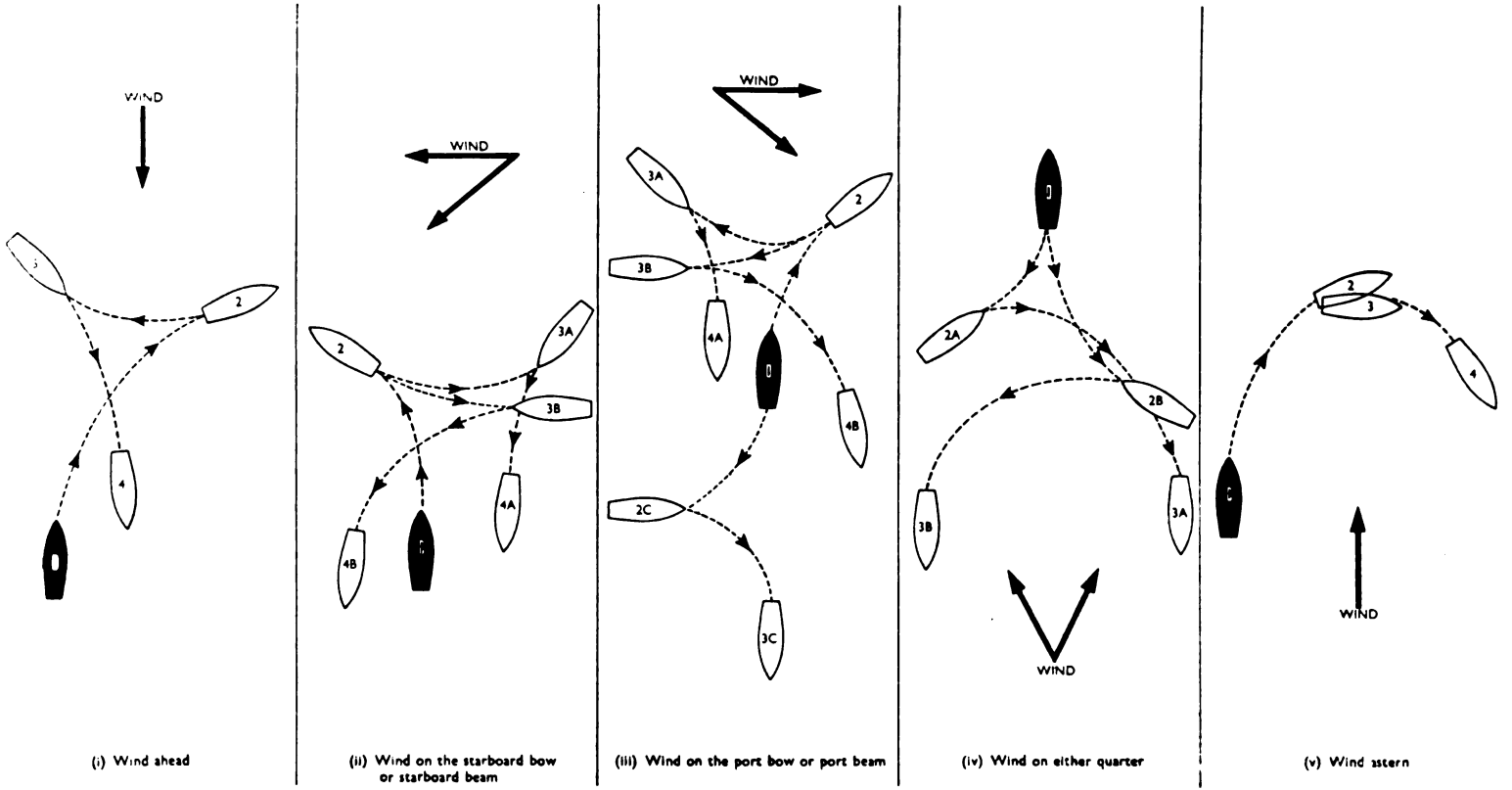

(i) Wind ahead

(ii) Wind on the starboard bow or starboard beam

(iii) Wind on the port bow or port beam

(iv) Wind on either quarter

(v) Wind astern

Fig. 13. Right-handed single-screw ship turning short in a wind

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(iv) the screw-effect of the propeller will be most marked when the ship has no way on her or is moving slowly ahead or astern, and the higher the speed at which the propeller revolves the greater will be its screw-effect.

The recommended methods of turning a single-screw ship short around in winds blowing from different directions are shown in Fig. 13. It is assumed that her pivoting point when going ahead is about amidships and that she has a greater windage area before her pivoting point than abaft it.

(i) *When the wind is directly ahead* the turn is best made by first going ahead with the rudder to starboard and then going astern with the rudder to port, as then full advantage is taken of the screw-effect of the propeller and the tendency of the stern to swing into the wind when making a stern-board. The turn can also be made by first turning to port under headway, but this takes longer and requires more sea-room.

(ii) *When the wind is on the starboard bow or starboard beam* the bows are first swung away from the wind by going ahead under full port rudder. The engine is then put astern and a stern-board made under full starboard rudder, which will swing the stern into the wind. The turn is completed by going ahead under full port rudder.

In the second stage the screw-effect of the propeller may kick the ship's stern to port as she loses headway, but as she gathers sternway her stern will swing into the wind. It is useless to try to turn first to starboard unless the bows can be swung through the wind before the engine is put astern, because when the engine is put astern the bows will fall off the wind as headway is lost and sternway gathered, and the ship will point in her original direction but farther to leeward.

(iii) *When the wind is on the port bow or the port beam* there are two equally good methods of turning short. One is to go ahead under starboard rudder and swing the bows away from the wind, then put the engine astern and make a stern-board into the wind, and then complete the turn by going ahead under full starboard rudder. The other method is first to go astern under full port rudder, make a stern-board into the wind, and then complete the turn by going ahead under full starboard rudder. Both methods take full advantage of the screw-effect and the tendency of the stern to swing into the wind when making a stern-board. It is useless to try to turn bows to port at the start, for the same reasons as were given in the preceding paragraph.

(iv) *When the wind is on either quarter* it is best first to make a stern-board into the wind, and then complete the turn by going ahead under full port or starboard rudder. The turn will be quicker and require less room when the wind is on the port quarter than when it is on the starboard quarter.

(v) *When the wind is directly astern* the turn will require considerable sea-room unless assisted by dropping an anchor and turning round it, as described on page 80. First the engine should be put ahead and the bows swung to starboard; then, when the wind is on the quarter, the engine should be reversed, and as the ship loses headway she should tend to lie broadside on to the wind and the screw-effect of her propeller should start to swing her stern to port. Before she gathers sternway the engine should

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be put ahead again with the rudder hard-a-starboard and the turn then be completed under headway.

A twin-screw ship will turn equally quickly in either direction when the weather is calm by working one engine ahead and the other astern, but the quickest swing will be obtained if she is kept moving ahead. If there is sufficient room it may even be quicker to gather headway and then, by varying the speeds of the engines, move far enough astern for another run ahead. Whether turning with or without slight headway on the ship the rudder should be put over towards the side to which the ship is turning; with headway on it will assist the propellers, and without it will offer least resistance to the turn.

In a wind a twin-screw ship can usually be turned short in any direction but the best method in any given circumstances depends largely on the tendency of her bows to swing into or pay off from the wind when going ahead, and this in turn will depend upon the position of her pivoting point when going ahead and the disposition of her superstructures before and abaft it. As when turning in calm weather, the turn will be executed more quickly with way on the ship. Full advantage should be taken of the tendency of the stern to swing into the wind when going astern, and of the screw-effect of the propellers in assisting the swing of the stern one way or the other. The tendency of the ship to lie broadside to the wind when slowing down or stopped should also be borne in mind.

Turning short round an Anchor

Letting go an anchor and holding it at short stay, and then steaming round it on a taut cable is a very useful method of turning a ship in the required direction where manœuvring room is limited. When doing this, however, two points must be borne in mind: first that the anchor should not be let go where it may foul the ground tackle of other ships and moorings, or the cables of telegraph and telephone services; secondly that the manœuvre must be made at slow speed and the cable be tautened very gradually, because the cable will be growing aft throughout the turn and so may be given a bad nip by the after edge of the hawsepipe, and it may then be easily parted by any sudden or undue stresses.

To carry out this manœuvre the wheel is first put over in the required direction with the ship steaming slowly ahead, then the anchor on the side towards which you are turning is let go. The engines are stopped and sufficient cable to hold the bows is allowed to run out on the brake while the way of the ship is reduced and the cable gradually tauntened. When the cable is taut the engines are put to slow ahead, and with the wheel over the ship is steamed round her anchor to the required direction.

When a wind is blowing it should be borne in mind that the ship will always swing head to wind when finally the anchor is weighed, and the usefulness of this manœuvre in a wind is therefore considerably restricted.

Securing to a Buoy

In calm weather securing to a buoy is a simple operation. The ship is headed for the buoy at slow speed and brought to rest with one of the hawsepipes over the buoy so that the ends of the bridles can be lowered through it directly to the buoy-jumpers. The approach should be made sufficiently slowly to allow the engines to be put ahead if necessary during the later stages in order to assist the rudder, and also in a single-screw ship, to ensure that her bows will not

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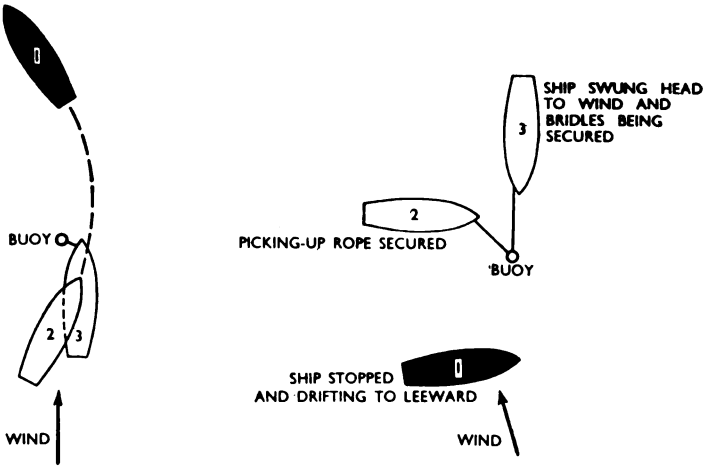
swing off too far when the engine is put astern. In a single-screw ship it is best to aim initially for a position a little to port of the buoy to allow for the swing of the bows to starboard as the way is taken off the ship.

Unless the wind is very light or dead aft it is almost impossible to keep a ship close up to her buoy. Even if the ship is stopped heading dead into the wind it will not be long before the bows pay off to one side or the other, and it will then be impossible to bring the ship head to wind again without gathering considerable headway. For this reason a ship should approach her buoy either before the wind or by making a stern-board into the wind.

A single-screw ship should secure with the help of a tug, but if one is not available she should make a stern-board into the wind on a course which will leave the buoy to port and bring the wind fine on her starboard quarter (see Fig. 14 (i)). Then as her sternway is taken off by putting the engine ahead the screw-effect will swing her bows to port towards the buoy and her stern into the wind.



(i) Single-screw ship securing to a buoy by making a stern board (ii) Making fast to a buoy other than stern to wind

Fig. 14. Securing to a buoy in a wind

In a twin-screw ship little difficulty should be experienced whichever method is used, provided that the ship is stopped stern to wind with the buoy under her bows.

If the buoy cannot be approached on a course directly into or before the wind the help of a tug is advised, but if one is not available it is best to stop the ship to windward of the buoy with her bows nearly abreast it. As the ship drifts to leeward the picking-up rope is made fast to the buoy and the ship will then swing round it, head to wind, and the bridles can be shackled on (see Fig. 14 (ii)). This method, however, should not be used if the ship is liable to get into difficulties should she fail to pick up the buoy.

Slipping from a Buoy

If there is no wind current or tidal stream when the buoy is slipped the engines should be worked astern until the ship is well clear of the buoy before

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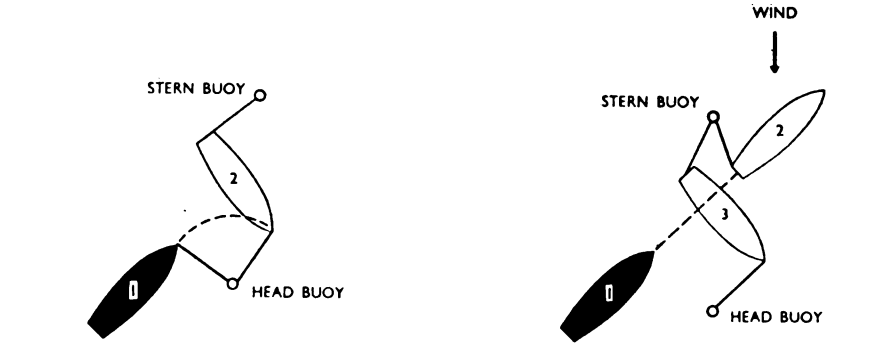
any attempt is made to turn in the required direction. Nothing is gained by turning with the buoy close under the bows, because not only is the ship's freedom of movement then restricted but the buoy may easily foul her propellers when she goes ahead.

If there is a wind the buoy will spring well clear of the ship when it is slipped and the ship's bows will start to pay off from the wind, so that it will then be possible to go ahead on the engines without first moving astern, the rudder being used to swing the stern clear of the buoy if necessary. In a tideway, the ship can be cast in the required direction by her rudder before slipping.

Unless unavoidable the slip-rope should not be slipped when there is a heavy strain on it, otherwise the slip may jump up or back and injure the man who knocks it off. The hauling end of the slip-rope should be surged until there is little strain on the rope, and the slip then be knocked off.

Securing head and stern between Two Buoys

In calm weather, and with plenty of room to manœuvre, the ship should be headed for the far side of the head buoy and at a fine angle to the line of the buoys, so that as she is stopped with her hawsepipe abreast the head buoy, her bows will swing towards that buoy and her stern towards the line of the buoys.



(i) Turning end for end before securing head and stern to buoys in calm weather

(ii) Turning end for end in a wind before securing head and stern to buoys

Fig. 15. Securing head and stern between two buoys

If manœuvring space is limited and the ship has to be turned end for end before securing to the buoys, a twin-screw ship with good manœuvring powers should be placed with her pivoting point in the position it will occupy when she is berthed, and she should then be turned round, care being taken to avoid gathering either headway or sternway during the manœuvre. In a single-screw ship, or a twin-screw ship of poor manœuvrability, it is best to head the ship for the centre of the berth and at a broad angle with the line of the buoys (see Fig. 15 (i)), and then stop her with her bows distant from the head buoy about one-third of the distance between the buoys. The picking-up rope is then secured to the head buoy and brought to the capstan, the engine put ahead with the wheel over, and the ship turned on the picking-up rope round the head buoy, while another picking-up rope is sent from aft to the stern buoy. After the ship has turned through 90 degrees both head and stern ropes are hove in by the forward and after capstans respectively, to centre the ship in her berth.

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Unless the wind is very light, or blowing along the line of the buoys, a single-screw ship should be secured with the help of tugs. A twin-screw ship, unless she is very handy, should also use tugs when a strong wind is blowing across the line of the buoys.

One method of securing when the wind is blowing across the line of the buoys is to place the ship abreast, and to windward of, her berth and then hook on the head and stern picking-up ropes as she drifts broadside into her berth, but unless the wind is light a tug is essential both forward and aft to control the rate of drift and to hold the ship in her berth while the bridles are secured. Another method when the wind is blowing across the line of the buoys, but one which is only feasible with a very handy ship, is to place the ship stern to wind with the head buoy under her lee bow. The head buoy is then secured and the wind allowed to swing the stern round to the stern buoy, the rate of swing being controlled either by going astern on one engine or by dropping a stream anchor.

With the wind blowing along the line of the buoys the approach should be made either before the wind or by making a stern-board into the wind, as when securing to a single buoy.

If the wind is blowing along the line of the buoys, if the berth can be approached from one direction only, and if the ship must be turned end for end before being secured, she can be turned round the head buoy as already described if approaching before the wind, but if approaching into the wind she must be turned and secured in the following manner :—

The ship is headed at an angle to the line of the buoys on a course which will take her a little ahead of the centre of the berth and between the buoys (see Fig. 15 (ii)). She is then stopped with her stern roughly on the line of the buoys, and the stern picking-up rope is secured to the stern buoy. The ship is then allowed to swing stern to wind on the stern buoy while the head picking-up rope is secured to the head buoy. The head and stern ropes are then hove in as before to bring the ship into her berth.

Slipping from Head and Stern Buoys

The forward and after slip-ropes can be let go together, and the ship be slewed by her engines to get the bow and stern clear; with a single-screw ship it may be necessary to use a tug if the space is very limited.

In a wind, if it is directly along the line of the buoys, the lee buoy should be slipped first. When the weather slip-rope is surged and let go the buoy will spring clear and the ship will tend to swing beam on to the wind. She can then go either ahead or astern, as necessary, to clear the berth.

If you want to leave by going either directly ahead or directly astern when the wind is on one side or the other, both slip-ropes should be surged until the ship lies well to leeward of the berth ; both slip-ropes should then be slipped together and the ship move off in the required direction. If it is necessary to leave the berth at an angle to the line of the buoys the ship can be cast in the required direction by slipping one buoy first and allowing the wind to blow her round before slipping the other.

Going alongside a Jetty

When going alongside a jetty the following factors which influence the handling of a ship must be borne in mind :—

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Single-screw ships :—

(i) When the engine is reversed to take the way off the ship the screw-effect of the astern-turning propeller will always tend to swing the stern to port and the bows to starboard.

(ii) The faster the initial speed of approach the greater will be the power required to stop the ship, and so the allowance made for the screw-effect must be correspondingly increased. The initial speed of approach should therefore normally be sufficient only to maintain steerage way.

(iii) The rudder is always most effective when the propeller is turning ahead, whether the ship has headway or sternway on her, or is stopped. Conversely, the rudder is least effective when the propeller is turning astern, particularly when the ship is stopped or has sternway on her.

(iv) When the ship is close alongside with her engine working astern, the wash of the astern-turning propeller between the side of the ship and a solid jetty will tend to kick the stern outward.

Twin-screw ships :—

(i) The effectiveness of the rudder decreases very rapidly as the speed of the ship is reduced, and at very low speeds, ahead or astern, or when the ship is stopped, it is almost completely ineffective, and its effectiveness is not then influenced by the movement of the propellers. The final manœuvring of the ship alongside is therefore effected largely by means of her propellers.

(ii) In order to carry steerage way for as long as possible before stopping the ship, the speed of approach is normally a little faster than that of a single-screw ship, because of the ineffectiveness of the rudder at low speeds. The speed of approach should, however, be the lowest that will give steerage way.

(iii) In the later stages of the manœuvre only the offshore propeller should normally be used for finally stopping the ship, because if the inshore propeller is used its wash between the side of the ship and a solid jetty will kick the stern outwards.

The ideal to aim at when going alongside a jetty is to place the ship abreast her berth, parallel with the jetty and a few feet from it, and with a very slight broadside drift towards the jetty. This ideal, however, is often unattainable, and one's first object should always be to place the bows close enough to the jetty to enable a fore headspring to be passed ashore to help in any subsequent manœuvring.

The method of executing the manœuvre in a single-screw ship depends on whether she is to be placed alongside starboard side or port side to the jetty, because allowance has to be made for the screw-effect when the engine is put astern. In a twin-screw ship the same method is used whichever side is to be next the jetty.

In a single-screw ship going alongside port side to in calm weather the approach should be made at an angle of from 15 to 20 degrees with the jetty, with the ship heading for a position a little ahead of where her pivoting point will be when she is in her berth. When her engine is put astern to stop her the screw-effect will swing her stern towards, and her bows away from, the jetty. If the rate of swing is too great it should be checked by the headrope, using it as a breast. If the ship has not been swung far enough when she is finally stopped,

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her stern can be breasted in if she has a capstan or a powerful winch aft, otherwise her stern can be swung in by going ahead on an after headspring.

When going alongside starboard side to in a single-screw ship the angle of approach should be rather finer, say from 10 to 15 degrees with the jetty, and the ship should be headed for the position where her pivoting point should eventually lie. As her bows approach the jetty the rudder should be put over to port and the engine be given a kick ahead to swing her bows away from, and her stern towards, the jetty. Just before the ship is parallel with the jetty the engine should be put astern to stop the ship, and the screw effect should then counter the ship's swing so that she is stopped parallel with the jetty and abreast her berth. As before, if the rate of swing is too great it can be checked by a headrope, and if the swing is insufficient the stern can be breasted in or swung in by using an after headspring.

In a twin-screw ship the angle of approach should be between 15 and 25 degrees with the jetty, and the ship be headed for the position where her pivoting point will eventually lie. As her bows approach the jetty her offshore engine should be put astern, and as the ship is stopped the screw-effect of the offshore propeller will then swing her stern towards, and her bows away from, the jetty. If the ship swings too quickly she can be checked by putting her inshore engine astern, and if too slowly her swing can be accelerated by putting the inshore engine ahead.

The best angle of approach and speed will differ with different types of ship, but generally speaking the broader the angle the more pronounced must be the initial swing to bring the ship parallel with her berth, therefore at this stage the speed must be sufficient to ensure that the ship is fully manœuvrable. If for some reason a normal approach cannot be made, as when ships are secured close ahead and astern of your berth, for example, the ship should be placed at as fine an angle as possible with the jetty and with her bows close in, and a headspring should then be passed ashore and secured. Then, by going ahead on the headspring, the ship can be swung parallel with the jetty.

When going alongside in a wind not only must allowance be made for any leeway during the approach but also for the slewing effect of the wind as the ship loses way, bearing in mind that with the rudder central and the engines stopped most ships will tend to swing broadside on to the wind as they lose way. In some circumstances the wind will combine with the screw-effect of an astern-turning propeller and increase any swing of the ship ; in others the wind will tend to counter the screw-effect and reduce or stop any swing.

The effects of both wind and screw-effect on a single-screw ship, and on a twin-screw ship, when stopping by reversing the engines, are illustrated in Fig. 16 and described below. In each of these examples it is assumed that each type of ship has her pivoting point a little before amidships and that she has a greater windage area before her pivoting point than abaft it. The lengths of the arrows in the illustration denote the degree of swing of the ship.

(i) *Wind on the port bow.*—In a single-screw ship, and also in a twin-screw ship when the starboard engine is going astern, the wind will combine with the screw-effect and appreciably accelerate the swing of the bows to starboard and the stern to port. In a twin-screw ship with the port engine going astern the wind will tend to counter the screw-effect and considerably reduce or stop the swing of the bows to port.

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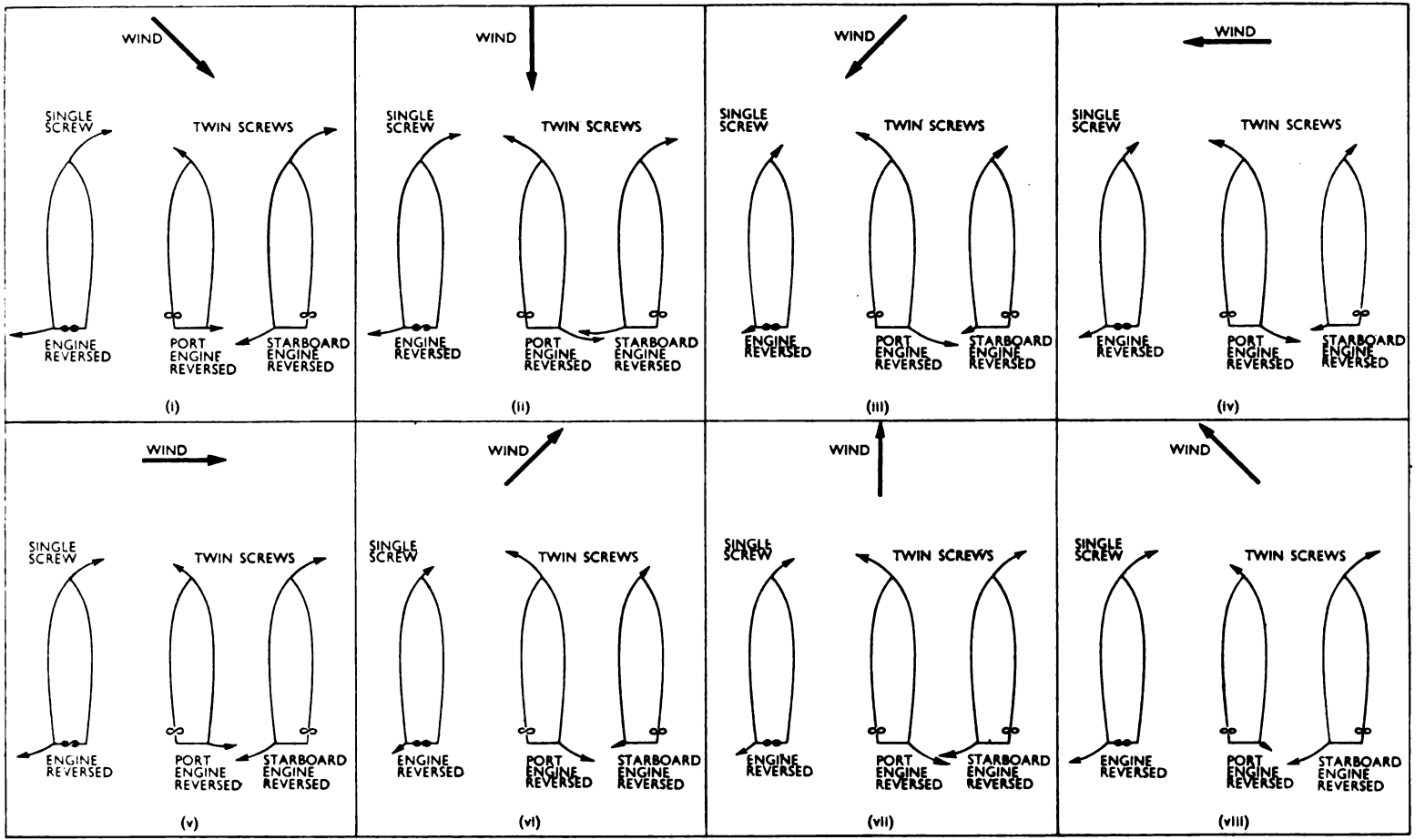

Fig. 16. Effects of a wind on single-screw and twin-screw ships when the engine is reversed to stop the ship

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(ii) *Wind right ahead.*—In both single-screw and twin-screw ships, at first the effect of the wind will not be very great, but as the swing initiated by the screw-effect develops and the wind gets broader on the bow its effect will increase considerably.

(iii) *Wind on the starboard bow.*—This is the reverse of example (i) The swing of a single-screw ship, and also of a twin-screw ship when the starboard engine is going astern, will be reduced or stopped, and the swing of a twin-screw ship with the port engine going astern will be accelerated.

(iv) *Wind on the starboard beam.*—In this case the effect of the wind will be similar to that described in example (iii), but not to such a marked degree.

(v) *Wind on the port beam.*—Here the effect of the wind will be the reverse of that described in example (iv).

(vi) *Wind on the port quarter.*—In a single-screw ship, and also in a twin-screw ship when the starboard engine is going astern, the wind will tend to counter the screw-effect and so reduce or even stop the swing. In a twin-screw ship with the port propeller reversed the swing will be accelerated.

(vii) *Wind right astern.*—In both single and twin-screw ships the effect of the wind will not at first be very great, but as the swing initiated by the screw-effect develops and the ship loses way the wind will tend to accelerate the swing. If sternway is gathered, however, the stern will tend to swing back into the wind.

(viii) *Wind on the starboard quarter.*—The effect of the wind will be the reverse of that described in example (vi).

To show the manner in which this knowledge is applied to a particular manœuvring problem five examples of the way in which a single-screw ship is manœuvred alongside in a wind are illustrated in Fig. 17 and described below. The wind is shown as blowing from five different directions in relation to the jetty, which is assumed to lie due north and south, and in each example the manœuvres are given for placing the ship alongside both port side to and starboard side to.

(i) *Westerly wind.*—When going alongside starboard side to, the ship approaches at a very fine angle with the jetty, due allowance being made for leeway, and heading for an imaginary berth abreast her proper berth but a ship's breadth off it. Before the engine is put astern a pronounced kick ahead under full port rudder is given to swing the bows towards the wind. The ship should be stopped with her bows pointing slightly away from the jetty, because as she drifts bodily to leeward the bows will pay off from the wind more rapidly than the stern, and then by the time she drifts into her berth alongside she should be parallel with the jetty. When going alongside port side to, the angle of approach should again be very fine and the ship be heading for a similar imaginary berth off the jetty. Just before the engine is put astern the bows are swung slightly towards the wind so that when the ship is brought to rest off her berth her bows will be pointing slightly out from the jetty, and she will then drift squarely into her berth.

If in each of these manœuvres the final drift of the ship into her berth is excessive and it appears she will bump heavily into the jetty her *inshore* anchor should be let go and her bows held by the cable ; the cable will then

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Fig. 17. Going alongside a jetty in a single-screw ship in a wind

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grow under the ship's bottom and thence slope gently to the anchor and so give the anchor a better chance of holding at the short stay available.

When going alongside starboard side to, the stern can be held up to the wind by giving a kick astern on the engine, and when going alongside port side to by giving a kick ahead under full port rudder.

It is emphasised that should a collision with the jetty be inevitable the ship should, if possible, be stopped at the moment of impact so that any resultant damage will be confined to a small area. If the ship has way on her at the moment of impact the damage will probably be very extensive.

(ii) *North-westerly wind.*—When going alongside starboard side to, the wind will be on the port bow throughout the manœuvre, which is carried out in a similar manner to that in example (i), except that the swing of the bows into the wind before the engine is put astern should, if possible, be more pronounced, and the ship be stopped a little ahead of her berth. When going alongside port side to, the wind will be on the starboard quarter throughout the manœuvre, and as the ship is stopped the wind will assist the screw-effect of the propeller to swing the stern towards the jetty. The approach is therefore made at a broader angle with the jetty than normally, and the ship is stopped a ship's breadth off her berth and a little astern of it with her bows pointing slightly towards the jetty.

(iii) *Northerly wind.*—In this case the ship goes alongside with her starboard side to in the same way as she would in calm weather except that initially she is pointed for the head of her berth. The astern power required to stop the ship will not be so great because the wind will help to retard her, and so the preliminary swing to port before the engine is put astern need not be so pronounced.

To go alongside with her port side to entails bringing the ship to her berth directly before the wind, and this is difficult because considerable astern power will be required to stop the ship and if at this stage the wind is brought on the starboard quarter of the ship it will combine with the screw-effect to swing her stern to port. When going alongside port side to, the ship is therefore headed at the normal angle of approach for an imaginary berth a little away from the jetty, and the engine is put astern earlier than usual to stop the ship.

If the ship can be manœuvred with a fair degree of accuracy when going astern it would probably be better under these circumstances to approach the berth stern to wind from a position to leeward of it, as shown in Fig. 17 (iii). As the stern-board is made the stern will come up into the wind, and the wind will assist in stopping the ship. At the same time the ship will be under better control when the engine is put ahead to bring her to rest.

(iv) *North-easterly wind.*—In an offshore wind the nearer the ship approaches the jetty the less will be the effect of the wind as she moves into the lee formed by the jetty, but because the bows will move into this lee before the stern there will be a strong tendency of the bows to swing towards the jetty as the wind blows the stern away from it, and due allowance must be made for this during the earlier stages of the approach. The broader the wind blows off the jetty the less will be its effect in the later stages of going alongside ; this should be allowed for during the later stages of the manœuvre.

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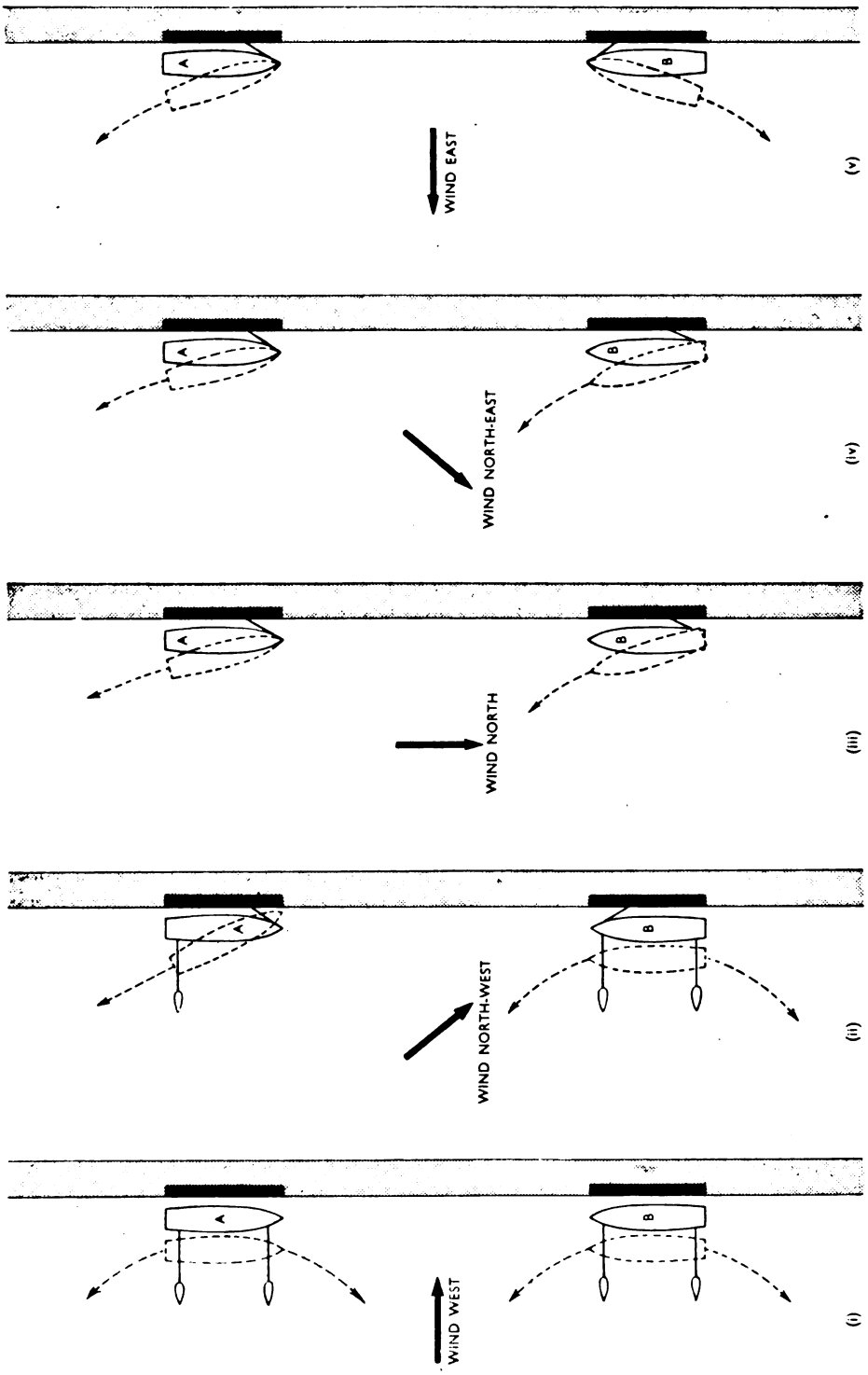

Fig. 18. Slipping from a jetty in a twin-screw ship in a wind

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In a strong offshore wind the ship should approach a little faster than usual to offset any excessive leeway. With an offshore wind it is essential that the head and stern ropes should be passed and secured quickly to prevent the ship from being blown off the jetty after she has been placed alongside.

When going alongside starboard side to, the approach is made at the normal angle, with the ship heading for the head of her berth. As the ship loses way the wind will tend to blow her bows away from the jetty, and so the preliminary swing of the bows away from the jetty before the engine is put astern need not be pronounced and in some ships may even be unnecessary.

When going alongside port side to, the wind will be on the port quarter and will tend to counter the swing of the stern to port as the ship loses way ; if her bows are then in the lee of the jetty the wind will blow her stern away from the jetty. The approach should therefore be made at a fine angle with the jetty, and before the engine is put astern her bows should be swung away from the jetty.

(v) *Easterly wind.*—Approaching from either direction the procedure is similar to that for going alongside in calm weather, except that the approach is made at a faster speed and at a much broader angle to offset leeway, and the ship is headed initially for a position at the after end of her berth. During the approach the wind will tend to blow the bows away from the jetty and as the ship is stopped parallel with the jetty the wind will tend to swing her bows out ; the headrope should therefore be passed and secured as soon as possible.

Slipping from a Jetty

In a single-screw ship the normal method of slipping from a jetty is to go ahead on a fore headspring so as to cast the stern out from the jetty and then, when the stern is far enough out, to go astern and cast off the headspring. The angle through which the ship must first be turned on her spring will depend on whether she is lying with her port or with her starboard side to the jetty, whether another ship is lying close astern of her, the force and direction of any wind, and the angle through which the ship must be turned after clearing her berth.

In an easily handled twin-screw ship such as a destroyer a spring need not be used in calm weather if there is a clear run astern, because her stern can be cast sufficiently far out by her propellers alone as she gathers sternway.

In a single-screw ship lying starboard side to in calm weather the stern should be cast well out, because when she goes astern to clear the berth the screw-effect of her propeller will kick her stern to port, and there is then a danger of her bows scraping along the side of the jetty before the ship clears her berth.

If, when she is lying starboard side to, it is necessary to wind the ship, *i.e.*, turn her right round before clearing her berth, it can be done by leading the spring through the foremost fairlead and bringing it to the capstan. The stern is cast out on the spring as far as possible, and the engine is then put astern. As the bows clear the jetty the spring is held or hove in, thus helping the swing of the bows to starboard, and the spring is then cast off as the ship gathers sternway.

In a single-screw ship lying port side to in calm weather the stern need only be cast out sufficiently to allow for the swing of the stern to port towards the

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jetty when the engine is put astern and to ensure a clear run astern. The kick of the stern to port will ensure that the bows are clear of the jetty as the ship clears her berth.

In a twin-screw ship the offshore engine is first worked slow ahead, and shortly after the inshore engine is worked slow astern, with the result that the ahead thrust on the spring is not excessive. In addition to the slewing effect of the propellers the wash of the inshore propeller between the ship's side and the jetty will help to cast the stern out. When the stern has been cast out sufficiently far the offshore engine is reversed to half speed astern followed shortly afterwards by putting the inshore engine to half speed astern, thus ensuring that the bows will swing out from the jetty as the ship gathers sternway. The headspring is cast off as soon as it slackens.

When slipping from alongside in a wind the chief considerations are the direction of the wind in relation to the ship, both when she is alongside and when she is clearing her berth, and consequently its probable effect in tending to force the bows or stern towards or away from the jetty, and its tendency to accentuate or counter any swing initiated by the propellers. It must also be borne in mind that when making a stern-board the stern will always tend to fly up into the wind.

How to slip from a jetty in a twin-screw ship, both when lying with her starboard side to and her port side to, and with the wind blowing from five different directions, is illustrated in Fig. 18 and explained below.

(i) *In a westerly wind* the help of tugs to haul the ship bodily to windward is most advisable because it will be difficult to cast the stern outwards against the wind by going ahead on a spring, and as the ship gathers sternway the stern will swing into the wind, with the result that the bows will swing towards the jetty and probably collide with it before the ship clears the berth.

(ii) *In a north-westerly wind* ship ' A ' will have the wind on her offshore quarter, and as it may be difficult to cast the stern outwards against the wind by going ahead on a spring it may be necessary to employ a tug to haul the stern out. Once the stern is cast well out there should be little danger of the bows fouling the jetty as the ship clears the berth stern first. The stern should not be cast through the wind, however, because if the wind gets on the inshore quarter the stern may be blown outwards and the bows swing towards and foul the jetty.

Ship ' B ' will have the wind on her offshore bow, and though her stern may be cast out by going ahead on a spring the wind will blow her bows on to the jetty as she clears the berth stern first. It is therefore advisable to employ tugs to haul the ship bodily clear of the berth before turning ahead or astern into the fairway.

(iii) *In a northerly wind* it should be easy for ship ' A ' to cast her stern out because the wind will help the manœuvre as soon as it blows on her inshore quarter. The stern should be cast well out because it will tend to fly into the wind as soon as the ship gathers sternway.

In ship ' B ' it is best to hold on to a backspring and allow the bows to be blown off the jetty before casting off the spring and going ahead to clear the berth.

(iv) *In a north-easterly wind,* though ship ' A ' could cast off all her hawsers and drift to leeward clear of her berth, it will be quicker for her to

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to cast her stern outwards on a spring and then clear the berth stern first.

Ship ' B ' could also drift clear of her berth, but it will be quicker for her to cast her bows off the jetty on a backspring and then go ahead to clear the berth.

(v) *In an easterly wind* both ships could drift clear of their berths, but it will be quicker for each to cast her stern out on a spring and then go astern to clear her berth.

Going Alongside, and Slipping from, a Ship at Anchor or Secured to Buoys

Going alongside a ship at anchor in calm weather is very similar to going alongside a jetty, except that the anchored ship is free to swing and will pivot round her stem, and the water pressure from your bows as you close the anchored ship will tend to swing her stern away if the approach is made too fast and at too fine an angle.

The approach in a twin-screw ship should therefore be made at an angle of about 15 degrees with the other ship, at slow speed, and with the ship headed for the bows of the other ship. The approaching ship is then stopped by reversing her outer engine in the normal manner, and the berthing hawsers, particularly the after ones, are passed and secured as quickly as possible. When alongside each other the ships should be kept apart by catamarans (usually provided by the anchored ship) and each should be well fendered at the break of the forecastle or just before amidships where first contact between the two ships is most likely to occur.

In a wind, particularly one of any strength, the anchored ship will probably be yawing which will make the manœuvre more difficult. The stem of a ship yawing at anchor traces a path like a figure of eight, as shown in Fig. 19; as the ship reaches the limit of her yaw to one side, in addition to her broadside movement, she will come up into the wind and, owing to the reduced area exposed to the wind, she will surge ahead; she will then drop back as she yaws to the other side.

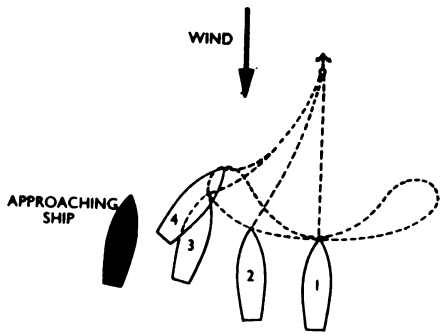

Fig. 19. Going alongside a ship yawing at anchor

Before going alongside a ship which is yawing she should be watched carefully to determine the extent of her yaw. The approaching ship should then be stopped just outside the limit of the other ship's yaw to one side, heading from five to ten degrees off the wind and pointing towards the anchored ship. Then, as the anchored ship again approaches the limit of her yaw to that side, the approaching ship can be edged in towards her and placed alongside her as she begins to yaw in the opposite direction. The manœuvre requires good judgment and smart handling of the berthing hawsers.

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When going alongside a ship secured head and stern to buoys athwart a wind or a tidal stream, the approaching ship will usually be set *towards* the berthed ship, whether she goes alongside her windward or leeward side, or her upstream or downstream side. This is because there is usually a contrary eddy close alongside the leeward or downstream side of the berthed ship. When approaching the leeward or downstream side it should be borne in mind that during the last stage of the approach the bows of the approaching ship will be in the lee of the berthed ship while the stern is still in the wind or stream, and due allowance must be made for this, otherwise the bows of the approaching ship will be set in sharply towards the berthed ship.

When slipping from a ship at anchor or secured to a buoy in calm weather it is useless to try to cast the bows or stern out on a spring because both ships will pivot together round the cable of the anchored ship. If all the hawsers are let go the ships will soon drift apart, and in a small ship this drift can be helped by bearing off the other ship.

In a wind it is best to let go the forward hawsers and hold on to the after ones until the bows of the two ships have swung sufficiently far apart, and then let go the after hawsers and go ahead when the sterns of the two ships are clear. Care must be taken not to allow the wing propellers of the two ships to foul each other.

Letting go an Anchor before going Alongside

In some harbours it may be necessary to let go an anchor before going alongside, so that when the ship subsequently casts off, her bows can be hauled clear of the berth by her cable. She then weighs her anchor and goes ahead into the fairway.

The anchor should be let go in such a position that when the ship is secured alongside, the cable grows abeam and with sufficient scope to ensure the anchor holding when the bows of the ship are subsequently hauled off; the shallower the water the closer to the jetty can the anchor be let go. If for some reason it is only possible to allow a very short scope of cable it is best to use the inshore anchor so that the cable leads under the ship's bottom to the anchor; there will then be a better chance of the anchor holding as the bows are hauled off. If, after clearing the berth, the ship has to turn by steaming round her anchor it should be let go some distance away from the jetty.

In calm weather the ship approaches at right angles to the jetty and pointing to the head of her berth, and as the anchor is let go at the required distance from the jetty the rudder is put over to swing the bows in the required direction. As the way of the ship is reduced the cable is braked to assist the swing of the bows, and a headrope is passed ashore and used to prevent the bows swinging out too far. The ship is eventually stopped a little more than half a ship's length ahead of her berth, when a stern rope is passed ashore and the ship backed stern first into her berth. In a single-screw ship allowance must be made for the screw-effect of the propeller as the ship is backed into her berth; if she is to lie starboard side to, her bows should be inclined away from the jetty when the engine is put astern, and if she is to lie port side to, her stern should be inclined away from the jetty.

In a wind the recommended methods of approach are as follows:—

If the wind would be before the beam when the ship is alongside, she should approach at right angles to the jetty as already described. If the

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wind is blowing onshore the ship is swung by it, and if blowing offshore she is swung by steaming round her anchor.

If the wind is blowing directly off the jetty, or if it would be on the ship's inshore quarter when alongside, she should first be placed alongside and the fore and after breastropes be passed and secured. The fore breast is then paid out until the bows are the required distance from the jetty, and the anchor is then let go and the ship hove back alongside.

With the wind blowing directly on to the jetty, or if it would be on the ship's offshore quarter when alongside, the angle of approach should be such that the wind will not blow on the inshore side of the ship. The anchor is let go at the required distance off the jetty and the cable veered as the ship drifts in before the wind, the force with which she strikes the jetty being minimised by holding her with the cable as required.

Slipping from Alongside with an Anchor down

When slipping from alongside with an anchor down the stern must be cast out on a spring or hauled out by a tug before the bows are hove out by the cable, otherwise the stern will foul the jetty and possibly damage the rudder or propeller. As the bows are hove out the stern must be held in position, either by the tug or by working the engine or engines against the cable, otherwise the stern may swing in again and foul the jetty. The heaving out of the bows should be controlled by a fore breastrope to prevent the ship from overriding her anchor.

In calm weather the help of a tug is not essential. In a single-screw ship, lying port side to, the stern is first cast well out on a spring, and then as the cable is hove in the engine is put slow ahead with the rudder to port. The ship's bows will be held by her cable while the screw-effect of the ahead turning propeller will tend to swing her stern to starboard and so move the ship bodily away from the jetty. In a single-screw ship lying starboard side to, her engine is put slow astern after her stern has been cast well out on a spring, and the cable is then hove in. The screw-effect of the astern-turning propeller will tend to kick the stern of the ship to port and so prevent it from swinging towards the jetty as the bows are hove off by the cable. Care must be taken while manœuvring that the ship does not gather any appreciable way and strain or part her cable.

In a twin-screw ship the inshore engine is put slow astern, and the offshore engine slow ahead, while the cable is hove in. The screw-effect of the propellers working against the pull of the cable will result in the ship moving bodily away from the jetty.

In an offshore wind the manœuvre is simplified because the wind helps to keep the stern from swinging towards the jetty as the bows are hove out, but the bows may swing out very rapidly unless they are controlled by a fore breastrope led from well forward.

In an onshore wind the help of a tug to haul the stern out, and to keep it from swinging in while the cable is hove in, is essential unless the wind is light and the ship particularly manœuvrable.

Entering and Leaving Harbour through a Narrow Entrance

The ship should approach on a course at right angles to the entrance from a position well clear of it; approaching parallel with the entrance and then

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turning into it or making an oblique entry between the pierheads should be avoided.

If a strong wind is blowing across the entrance the ship must approach from a position sufficiently far to windward of it to allow for the leeway she will make during her approach. As the bows of the ship enter the lee between the pierheads the wind will swing her stern to leeward, to counter which she must be given lee rudder. In a strong cross wind the entry between the pierheads should be made at as fast a speed as is prudent in the circumstances, because at slow speed the ship might be blown on to the lee pierhead.

A ship may not be able to head at right angles to the entrance when leaving harbour, because of lack of manœuvring space. St. Helier Harbour, Jersey, is a typical example where outgoing ships approach the entrance parallel with the mole and then have to turn sharply 90 degrees to starboard to pass through the entrance. This sharp turn is made by leading a warp from the shore through the foremost fairlead and bringing it to the windlass or capstan. Then, as the ship approaches the entrance under full rudder, her head is warped round until she is headed in the right direction ; the warp is then cast off and the ship goes ahead through the entrance.

Mooring Stern to a Jetty

In some harbours, owing to insufficient berths alongside, some ships have to moor their stern to a jetty. The ship first lets go one, or both, of her anchors off the berth and parallel with it, and then goes stern first into the berth where she is secured by stern hawsers led from each quarter to the jetty.

If both anchors can be weighed simultaneously it is better to moor with two anchors and spread their cables at an angle of about 20 degrees than to use one anchor, because the ship will then be held more securely in her berth in a wind, whatever its direction.

Such a berth may be dangerous, however, in a strong beam wind because she is then virtually moored by a span, like a ship moored between two anchors and riding at open hawse. If a full gale blowing from abeam is forecast it would be advisable to cast off, unmoor, and anchor in a safer berth.

In calm weather the normal approach for a single-screw ship is roughly parallel with the jetty and heading for the position where the first anchor is to be let go ; on reaching this position the offshore anchor is let go while the ship continues to move ahead. When the ship reaches a position which will give the required spread to her cables the second anchor is let go, and with headway still on the ship she is turned on the first anchor while the cable of the second anchor is allowed to run out so that it will not check her swing. The angle through which the ship is turned depends on whether the turn is to port or starboard, because allowance must be made for screw-effect as the ship is backed into the berth. If the turn is to port it is continued until the stern swings past the line of the berth, but if to starboard it is checked before the stern swings in line with the berth. When the stern is pointing in the required direction the engine is put astern until the ship has gathered sufficient sternway, and the cables are then veered. When the stern is sufficiently close to the jetty the stern hawsers are passed, and the cables are braked to stop the ship, but immediately the way is off the ship the cables must be veered roundly or their weight will spring the ship ahead before the stern hawsers can be secured.

A twin-screw ship is handled in a similar manner, but because of her greater

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manœuvrability there is no need for her to turn stern on to the berth by turning round one of her anchors. When she is stopped with her stern to the jetty it is advisable to keep both engines moving very slowly astern to prevent the ship being sprung ahead by her cables while the stern hawsers are being secured.

A wind blowing directly on to the jetty makes the manœuvre easier because it will help the ship to swing stern to the jetty on her anchors.

If the wind is parallel with the jetty and astern of the ship during her approach, her bows should be swung slightly away from the jetty before the anchors are let go to ensure getting the wind on her offshore quarter, as this will assist to turn the ship stern to the jetty. She should not be allowed to swing too far, however, and sternway should be gathered when her stern is still pointing to windward of her berth. As she moves astern the cables will at first slacken as the bows pay off from the wind, but immediately afterwards they will tauten, and straighten the ship on a course which will bring her to windward of the berth. Stern hawsers are then passed and secured as the ship drifts into her berth.

If the wind is parallel with the jetty but ahead of the ship during her approach she can still be turned on her anchor, but it will be a slow process requiring considerable engine power. Sternway should not be gathered until the stern is pointing to windward of the berth, and the manœuvre is then completed in the way just described.

Another method when the wind is parallel with the jetty and ahead of the ship during her approach, and one which is particularly suitable for twin-screw ships, is to approach parallel with the jetty but as close to it as possible. The rudder is then put hard over and the engines are worked so that the ship is stopped broadside on to the wind and a little ahead and to windward of the positions in which her anchors are to be let go. Then, as the ship drifts to leeward, her engines are put astern and first the weather anchor and then the lee anchor are let go. As the ship gathers sternway her stern will tend to come up into the wind and her bows to pay off, but the swing of the bows can be checked by the windward cable and the ship should eventually come to rest broadside on to the wind and to windward of her berth. She is then secured as before.

When the wind is blowing directly off the jetty a single-screw ship will have great difficulty in turning stern to wind and then in backing with any accuracy into her berth, and the help of a tug is, therefore, strongly recommended. A twin-screw ship, however, should experience little difficulty in turning stern to wind and then backing into the berth.

Unmooring when secured by the Stern to a Jetty

When slipping from a stern-to berth there is little advantage in keeping a sternrope rove while the cables are hove in because it will have little effect in checking any swing of the stern, and it may well foul the propeller and hamper any subsequent manœuvres as it is eventually hauled in. It is best, therefore, to let go all hawsers and allow the ship to ride freely over her anchors as they are weighed.

When the last hawser is let go the ship will surge ahead and may override her cables, but there is no harm in this because the weight of the cables when they grow aft will soon bring the ship gently to rest ; then, as the cables are hove in, the ship will be drawn over her anchors.

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If the ship has to turn through a large angle immediately after weighing, the anchor on the opposite side to the turn should be weighed first and the ship then turned on the other anchor.

In a wind from any direction, and whichever way the ship has to turn after weighing, it is best to allow her to swing naturally to the wind while her anchors are being weighed. It is useless to try to head the ship in any other direction by steaming round the anchors, because she will always swing head to wind as the second anchor is weighed.

When a ship is being unmoored in a beam wind with another ship moored close to leeward, her engine should be worked ahead to get her clear of the berth and her bows then be swung into the wind. As soon as her stern clears the bows of the other ship her engine is put astern and she will bring up a little beyond her anchors, which are then weighed as she swings to her cables.

Precautions, and Action in Emergency

Critical and unpredictable situations may arise very suddenly when manœuvring in narrow or crowded waters, and to cope with them quick decisions and immediate action are necessary. Such situations may be caused by an error of judgment, an unexpected manœuvre by a nearby ship, failure of engines or steering gear, misinterpretation of an engine or wheel order, or an unexpected squall or shift of wind.

To guard against any failure of the engine-order telegraphs and the siren, they are always tested as a matter of routine before the ship gets under way, but they should also be tested before a ship enters harbour or approaches pilotage waters after an ocean passage.

If a wheel or engine order has been misinterpreted it is best to order the wheel amidships, or stop the engine, before again giving the correct order. Experience has proved that the mistake will be corrected more quickly in this way than by reiterating the original order.

Generally speaking, ships should always be handled in narrow waters at slow or moderate speed ; excessive speed is unseamanlike and may well lead to confusion and accident. This does not mean that the movement of the engines should always be confined to slow speed ; in single-screw ships particularly, some manœuvres necessitate the propeller being driven at high speeds ; it is the speed of the ship through the water that must not be excessive.

When manœuvring in a harbour both anchors should always be ready for letting go immediately. If the way of a ship has to be checked by her ground tackle in an emergency both anchors should be let go rather than one, because it is better to lose both anchors if this will avert a collision, than to save one and suffer a collision.

Accidents can often be prevented by the quick and intelligent use of hawsers, and men should be trained in the expert handling of hawsers and heaving-lines, and these should always be ready at hand.

Even when an accident appears inevitable there is often some action which, if taken immediately, will minimise the damage, and the ability to take such action is one of the requirements of a good seaman. The nature of the action will depend upon circumstances, but it may also depend on the type and construction of the ship, and the officer-in-charge should, therefore, know how best his ship can withstand an impact. In quiet moments on the bridge he should think out the best action to take in different emergencies, so that when one

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actually arises he will take the correct action immediately and instinctively. In this connection the following are worthy of consideration :—

(i) The consequences of an accident should be taken into account. If the choice lies between colliding with another ship and going aground it may, in certain circumstances, be preferable to confine the damage to one ship by running her aground. (If the captains of the two ships which collided and exploded in the approaches to Halifax harbour in 1916 could have foreseen the disaster which resulted, it is reasonably certain that each would have run his ship aground rather than risk the collision.)

(ii) The most vulnerable parts of a ship's hull, and those where extensive damage is most difficult to repair, are the bilges, the propeller shafts, the propellers and the rudder. If grounding is inevitable it is therefore preferable to ground head on than to attempt to turn and so risk ripping open the bottom of the ship.

(iii) If collision with another ship is inevitable the damage can be minimised by striking her a glancing blow, preferably bow to bow, quarter to quarter, or bow to quarter. Striking the other ship head-on amidships or turning athwart her bows and so allowing the other ship to strike yours amidships must, if possible, be avoided. A ship is very vulnerable amidships because any serious underwater damage there will flood her largest compartments, *i.e.*, the boiler-rooms and engine-rooms, and when these are flooded the ship may founder.

(iv) Although ground tackle is used with discretion when manœuvring a ship to avoid fouling moorings, cables, and the ground tackle of other ships, there should be no hesitation in using it in an emergency to check a ship's headway, or to turn her, or prevent her from drifting onto a lee shore.

(v) If collision with a jetty is unavoidable it is better to turn and strike it a glancing blow than to strike it head on. The resulting damage will probably be above the waterline and not so extensive as that caused by a head on collision. If the ship is being blown broadside on to a jetty it is important that there should be no way on the ship at the moment of impact, otherwise the damage may be extensive. A broadside movement may be checked to a certain extent by a movement ahead or astern, but any such movement must be arrested before impact with the jetty.

MANŒUVRING IN A TIDEWAY AND IN A RIVER

A tidal stream, unlike a wind, does not affect a ship's actual manœuvring capabilities in relation to the water ; it will not therefore slew the ship or affect her turning qualities. What has to be taken into account when handling a ship in a tideway is the distance and direction the ship will be moved by the stream during any manœuvre. It should also be remembered that when the ship is secured by a hawser or her cable to the shore or the bottom, her rudder will be as effective as when the ship is moving ahead in still water at the speed of the tidal stream ; also that when secured alongside, any hawser leading forward or aft will act as a spring. If the rudder is put over when the ship is at anchor in a strong tidal stream, the ship will move bodily to that side as soon as the ship's head pays off, owing to the stream bearing on the opposite side of the ship.

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In comparing the relative effects of wind and tidal stream on a ship manœuvring in a tideway, that of the wind is far less than one would expect ; it needs a strong wind to offset the effect of a tidal stream of even half a knot.

The strength of a tidal stream often varies in different parts of a harbour and in places, off pierheads and close inshore for example, the direction of the stream may be reversed by eddies. Local knowledge is invaluable, and a good lookout should be kept for variations in the strength and direction of the stream, which in some places, such as the sides of a channel, may be so marked that one end of the ship will be more affected than the other.

Going Alongside and Slipping from a Jetty

A jetty is usually built so that it lies parallel with the direction of the tidal stream, and at such jetties ships should always berth against the stream. To go alongside against the stream is comparatively easy because the ship is less likely to overshoot the berth ; the stream helps to reduce her headway and so less astern movement of the engines is required to stop her.

When slipping from a solid jetty it does not matter whether the ship is heading upstream or downstream. By easing up or letting go the upstream hawsers and holding on to the downstream spring the pressure of water between the ship and the jetty moves the upstream end of the ship away from the jetty and at the same time forms a cushion which prevents the downstream end of the ship from swinging in to the jetty. If the ship is heading upstream the fore breastrope should not be let go until it is certain that the bows will not pay off too quickly and so cause the stern to swing in dangerously.

With a jetty built on piles the initial cast outwards will be considerably less than with a solid jetty.

Passing through a Narrow Entrance

Only small or medium sized ships should attempt to pass through a narrow entrance without the aid of tugs and warps, and this is one of the few occasions of handling ships in restricted waters when high speed is advisable, particularly if a strong stream is running across the entrance.

When the stream is running across the entrance the ship must approach at right angles to it from a position sufficiently far upstream to allow for the set during the approach. As soon as the ship's bows enter the slack water between the pierheads they will be swung towards the upstream pier because the stream will still be acting on her stern, and the instant this swing starts, full rudder must be applied in the opposite direction and the engines be worked boldly ahead. In a particularly strong stream it may even be necessary to stop the downstream engine and put the upstream engine to full ahead to counter the swing of the stern towards the downstream pier.

Manœuvring in Rivers

On straight reaches a river current usually runs more strongly in mid-channel than at the sides, and this should be remembered when the ship is slewed across the channel, because the current may then affect one end of the ship more than the other. On bends the current usually runs strongest and deepest along the outer bank of the bend, and there may be slack water, or even a reverse current, along the inner bank just down-river of the bend.

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When negotiating a particularly sharp and narrow bend in a long ship it should be remembered that the current will tend to swing the up-river end of the ship towards the outer bank as she turns round the bend. This is illustrated in Fig. 20, which shows a ship negotiating a sharp bend with the current.

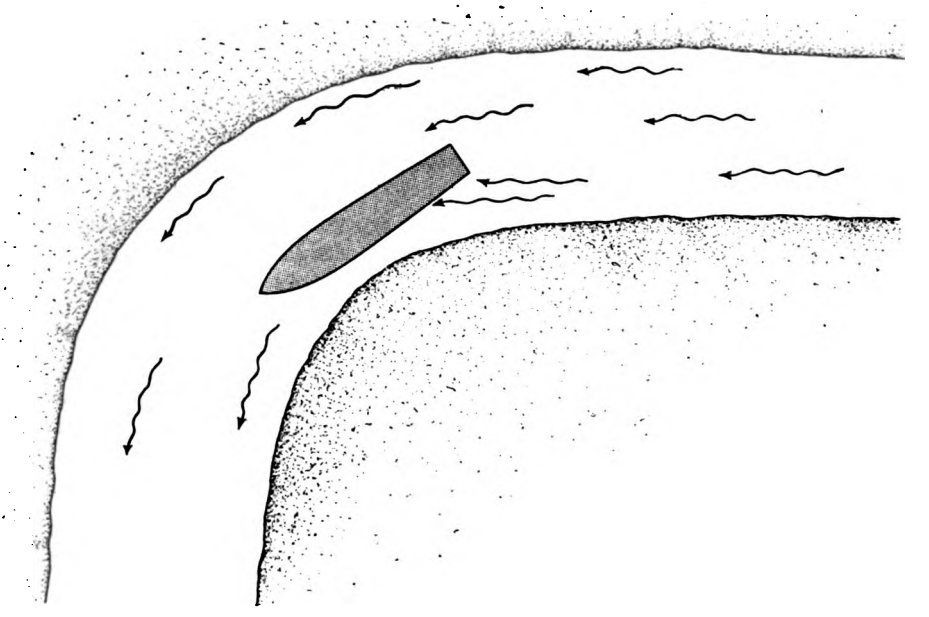

Fig. 20. Effects of a river current on a ship going round a narrow bend

When going up river the swing of the bows outward as they reach the bend must be forestalled. When going down river opposite rudder must be applied while the ship is still turning round the bend, to counter the swing of the stern outwards. When negotiating sharp and narrow bends it is usually best to keep to the outer side of the channel when going upstream and to the inner side when going downstream. It is a fairly general rule that ships should not pass each other on sharp and narrow bends.

A wind may, according to the direction in which it is blowing, tend to increase or decrease the swing of a ship as she turns round a bend. Probably the most difficult situation is that of a lightly laden single-screw ship, proceeding down river and before the wind, when negotiating a sharp bend to starboard. As the ship turns round the bend both the current and the wind will tend to swing her stern towards the outer bank; if this swing gets beyond control reversing the engine will only increase the rate of swing because of the screw-effect of the propeller. Under these conditions it is most important to keep the swing of the ship under control from the moment she starts to turn.

To turn short round in a multiple-screw ship when going down river, close one bank, then put the wheel hard over towards the opposite bank and put the inner engine astern; as soon as the ship starts to swing let go the up-river anchor and hold it at very short stay so that it drags over the river-bed. The drag of the anchor will help the swing of the bows up river and it will also lessen the drift of the ship down river during the turn; there is no danger of the cable

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parting if the anchor is kept at short stay. In a single-screw ship the turn is executed in a similar manner, except that she should close the bank on her port hand and make the turn to starboard.

MANŒUVRING WITH THE HELP OF TUGS

When a ship is being handled with the assistance of tugs, a harbour pilot who knows their capabilities and limitations will usually be on board the ship. Sometimes, however, the master or captain of a ship may have to give the necessary orders to the tugs himself, and he should therefore know how to use them.

Orders to the tugs should be passed by mouth-whistle and handflags; shouting orders and gesticulating usually leads to confusion, particularly in a foreign port, and should be avoided. Where ports have a standard code of whistle-signals for use with tugs they should invariably be used.

Girding

The danger of "girding" a tug must be emphasised. A tug's towing-hook is situated near her centre of gravity, and if the towrope when under strain is allowed to lead abeam from the tug she will be "girded" (*i.e.*, unable to turn) and so will be hauled broadside through the water; unless the towrope is then immediately slipped the tug will heel over and probably capsize. Because of the awkward lead of the towrope, or because she is listing heavily, it may not be possible to slip the towrope in the tug, and it must therefore always be secured in the ship by a slip which can be knocked off immediately in an emergency.

Perhaps the manœuvre which most commonly leads to girding is that of slipping from alongside when tugs are used to tow the ship broadside on to clear her berth; if when clear of the berth the ship then moves ahead or astern without warning, or without waiting for the tugs to turn parallel with her, they will inevitably become girded.

Going Alongside

When tugs are used to assist a ship in going alongside they are more usually employed in pushing the ship than in towing her. If two tugs are available one is placed forward and one aft, and any others are placed amidships or as required to adjust the angle of the ship with the jetty. To move a ship broadside on in calm weather without slewing her, a single tug should push at a point as near as possible abreast the ship's centre of gravity.

In an offshore wind the exact position at which a single tug should push to place a ship alongside a jetty is not always easy to estimate, but it will probably be somewhat before her centre of gravity. It is preferable with a twin-screw ship, or a single-screw ship going alongside port side to, to have the tug on the inshore bow; then, towing at short stay, the tug hauls the ship ahead and to windward, the ship's headway being checked as necessary by working her engines astern. In a twin-screw ship the appropriate propeller should at the same time be worked so that its screw-effect moves her stern to windward; the ship will then move bodily towards the jetty.

Another method of berthing in an offshore wind, which is applicable to single-screw ships going alongside with either side to when there is insufficient room

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for the tug to tow, is for the tug to push the ship stern first into her berth. The ship first places herself ahead of the berth and roughly parallel with it. The tug then pushes at full power, at a fine angle, on the offshore bow while the ship's engines are worked ahead but very slowly, so that the ship will move astern. The ship can then be easily steered owing to the slipstream from the ahead-moving propeller acting on the rudder, but it must be remembered that the effect of the rudder will cause the ship to handle as if she were actually moving ahead.

Slipping from Alongside

If two tugs are available one should secure to the ship's bows and the other to her stern, by a short towrope led from the towing hook, and then tow the ship off the jetty broadside on. When well clear of the jetty the tugs can be slipped if no longer required, but they are often kept in attendance to assist the ship out of harbour. If the tugs are kept the ship should not go ahead until the leading tug has moved ahead of her and is ready to proceed, and the other, which will usually be towed stern first, has shifted her towrope from the hook to a position right aft, otherwise the tugs may become girded. Any additional tugs should be towed alongside, or be paired off with the head and stern tugs.

If a ship has to be hauled off a jetty by only one tug and she need not turn completely round before proceeding, the tug should tow from a point about midway between the stem and amidships, and the ship will then be drawn off obliquely with a tendency to move ahead. If her stern shows signs of dragging along the jetty a movement ahead on the engines, with the wheel hard over towards the jetty, will keep it clear.

In a moderate wind blowing on to the jetty a multiple-screw ship can be towed clear by a single tug. The tug should be secured to the ship at a point about midway between her stem and her pivoting point, and tow at right angles to the ship's side. As the tug takes up the tow the ship should work her engines, as when turning at rest, to swing her bows towards, and stern away from, the jetty ; the ship will then be moved out bodily from the jetty.

Turning Short

When a ship has to be turned round by a single tug after casting off and the room available is limited, the tug should be secured right aft and tow the stern off while steering to keep herself at right angles to the ship. Meanwhile, the ship should steam ahead against the fore headspring in the usual manner, with the rudder hard over towards the jetty. When cast to an angle of about 45 degrees with the jetty the ship should work her engines slowly astern with the rudder turned away from the jetty, then slip the spring and headrope, and continue this movement until she has been turned through another 45 degrees, or as far as space permits. The engines and rudder should then again be reversed and the tug tow at full speed. During this last stage the ship will swing very rapidly and the tug must be slipped before the ship is steadied on her course and starts to move ahead. In the first part of this manœuvre adequate fenders are required between the bows and the jetty.

The simplest and quickest method of swinging a ship round in narrow waters on other occasions is to make the tug push against the ship a little abaft her stem and at right angles to the curve of her bows. This will push the ship's bows round and at the same time push her astern, at a rate depending upon the angle

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in relation to the ship's fore-and-aft line at which the tug is pushing. If, however, the engines are then worked ahead to check the sternway and the rudder put hard over, the ship will slew rapidly without gathering way.

When using a paddle tug secured alongside to slew the ship round, the tug's hawsers should be led in as far forward and aft in the ship as possible so as to obtain the maximum leverage.

Navigating Narrow Channels

One or more tugs are commonly used ahead of large ships when negotiating narrow channels with sharp bends. With a tug ahead the speed of the ship must always be a little less than that of the tug in order to keep the towrope taut. Before reaching a bend the ship's speed should be still further reduced so that the tug can tow with the maximum effect in the required direction when altering course. If speed is not reduced the tug must continue to head in the same direction as the ship to prevent herself being girded.

DOCKING AND UNDOCKING

The operations of docking and undocking ships described here are those carried out in the Royal Dockyards; the methods used by other yards are, in general, very similar.

Conditions required

In tideless waters, or in a basin, a ship can be docked or undocked at any time. In tidal waters, however, the docking and undocking of a ship depend upon the depth of water over the sill of the dock and upon the state of the tide, and the operations are usually begun at from 1½ hours to one hour before high water, so that the ship can be docked or undocked, and the dock gates be closed, at or just before the time of high water.

At some ports, Chatham river docks for example, the neap rise may give insufficient depth of water over the sill of the dock for certain ships to be docked at that tidal period.

Preparation in the ship

All fairleads and bollards should be clear and ready for taking the docking-hawsers, and bollard strops and slips should be provided forward and aft. Each part-of-ship should provide at least four heaving lines, two on each side, and though it is customary for the dockyard to provide the docking hawsers the ship's berthing hawsers should be ready for use. The ship's side should be clear of obstructions which might interfere with the handling of hawsers; all side-scuttles and ports should be closed, accommodation ladders be hoisted inboard, davits and boats be turned in, the leadsman's chains be unshipped or topped up, and all cranes, derricks and boat-booms should be housed. Awnings should be furled, the anchors be hove home but otherwise ready for letting go, and any retractable underwater fittings, such as asdic domes and bottom-logs, should be housed.

It is essential that the ship should have no list before docking, also that she should be trimmed either level or slightly by the stern, unless directed otherwise by the dockyard officers.

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A berthing-party may be required by the dockyard to assist in handling the hawsers; if so they should be sent to the dock before the ship leaves her berth.

Docking Hawsers

The hawsers usually required for docking a ship are listed below: they are passed in pairs, one on each side (the weather one first), in the following order :—

(i) first fore-guys, which are led through the foremost bow fairleads;
(ii) docking-springs, which are led from ahead through the fairleads abreast the break of the forecastle or just before the bridge; in small ships such as destroyers, however, one docking-spring only is passed, and it is led from right ahead through the bullring;
(iii) second fore-guys, which are led through the fairleads abreast the bridge;
(iv) first after-guys, which are led through the fairleads abreast the after superstructure or near the after gangways;
(v) second after-guys, which are led through the aftermost quarter fairleads.

The springs are used to warp the ship ahead, and the guys to square the ship so that she lies along the centre-line of the dock. The after-guys are also used to take the way off the ship, and it is important that when these are passed they should be secured as quickly as possible, because this is a critical stage of the operation.

Preparations in the Dock

Flat-bottomed vessels are usually built with side docking-keels, and for such vessels three lines of keel blocks are provided, but no bilge or breast shores. For vessels with rising bilges one line of keel blocks and bilge and breast shores are provided. The keel blocks are laid along the bottom of the dock and the shores are laid on the dockside within reach of a dockside crane. Breast shores are provided with lanyards at each end to enable them to be floated to their positions and manhandled into place.

Stars, each with the name of the ship, are painted on each side of the dock, two forward and two aft, to indicate the exact position in which the stem and the stern of the ship should be. Other marks may also be painted on the dockside to indicate such positions as those of the " cut-up " (the after end of the keel), the propellers, and the asdic dome.

Catamarans with brooms and scrapers are provided for the men who scrape the ship's bottom as the dock is pumped dry; they are usually secured in one corner of the dock. The docking hawsers are provided, and light tripping lines are rove across the dock at intervals to keep the bights of the fore-guys and springs clear of the bottom of the dock as the ship is warped in; they are tripped and hauled clear as the ship approaches them. Other gear provided includes: tackles, slings, and strops for the shores; docking tackles, which are clapped on to the guys and used to square the ship in her correct position as the dock is pumped out; and plumb-bobs and docking-bobs, which are used to ensure that the ship is upright and in her correct position.

When preparations are complete the dock is flooded to the same level as the water outside, and the caisson is then removed or the dock gates opened. A diver is usually in attendance while docking.

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Entering the Dock

The ship is towed from her berth to the dock, the number of tugs varying with the size of the ship; for a cruiser three tugs are usually employed, one ahead, one astern, and one secured alongside amidships. A pilot is usually in charge and the ship is manœuvred by the tugs alone; if her engines are used at all it is only during preliminary manœuvring and in emergency.

The ship is headed for the dock entrance and then placed by the tugs with her bows just inside the entrance and pointing directly up the centre-line of the dock. The fore-guys are then passed and secured, and the ship is warped into the dock while the tugs at her quarters help to keep her stern in the correct line.

If the fairway opposite the dock is narrow and a tidal stream is running across the dock entrance, the ship may be placed alongside the dock wall just upstream of the entrance and heading downstream, with a tug secured to her inshore quarter (see Fig. 21). A hawser is then passed from the tug to a bollard upstream of her, and the first fore-guys and springs are passed to the ship and secured. The tug then surges her hawser, thus allowing the stream to swing the stern of the ship out from the wall, and at the same time the bows of the ship are warped round the knuckle of the dock while the tugs help to keep her correctly positioned.

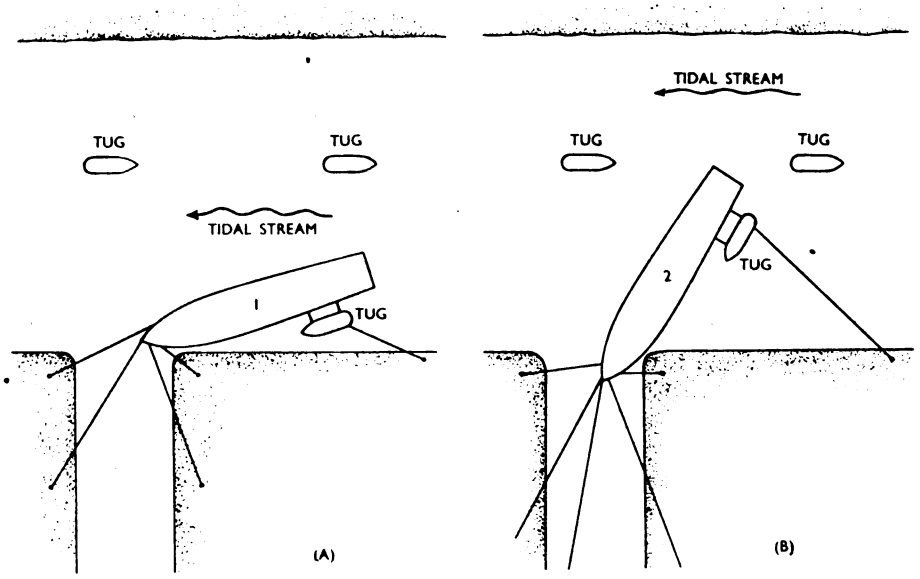

Fig. 21. Warping a ship into a dock entrance when a tidal stream is running across it

Docking

From the moment the first fore-guys are secured in the ship the representative of the Captain-of-the-Dockyard is responsible for docking her. The docking-springs are taken to capstans at the head of the dock, and the guys, which are passed successively in pairs as the ship is warped through the entrance, are taken to bollards on each dockside. The officer-in-charge signals his require-

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ments by whistle and handflags to the men working the hawsers and capstans, and to the pilot in charge of the tugs. As the ship is warped up the dock by the springs the guys are taken forward from bollard to bollard and worked as required to breast the ship squarely in the dock, and just before the stern passes over the sill the tugs are cast off.

When the stem of the ship is a few feet from the stem-marks this fact is signalled to the officer-in-charge of docking, who then brings up the ship on the guys. Finally, the ship is squared off in her correct position by the guys and springs and then secured by two fore-guys, one on each bow, and two after-guys, one on each quarter. One or two brows are then placed by a dockside crane.

Docking-down

When the representative of the Constructive Manager is satisfied that the ship is correctly placed in the dock, he takes over the charge of operations and orders the docking-tackles to be rove. The docking-tackles are hooked on to the middle of the spans of the two fore-guys and the two after-guys, and then led at right angles with the guys to bollards on the dockside and set up. The ship's position in the dock can be very accurately adjusted in this manner and she can be securely held there by bowsing down the guy tackles.

A diver may be sent down to ensure that the grooves in the sill of the dock are clear, and the caisson is then replaced. " Sewing-marks " are then chalked on the stern and on each side of the stem, one on the waterline and one six inches above it ; these indicate the fall of water as the dock is pumped out and after the ship has been " sewed " (grounded) on the keel-blocks. Plumb-bobs are rigged in hatchways or trunks forward and aft in the ship to check that she is upright, and docking-bobs are rigged over the centre-line of the dock, just before the stem and just abaft the stern of the ship, to check that the ship is lying along the centre-line of the dock as she is sewed. (The docking-bob is a light wire rigged across the dock with a ring at its centre ; the plumb-line is rove through the ring and tended on the dockside, and its length is adjusted so that the tip of the bob is kept just immersed.)

All brows, except one which is slung on a crane, are now removed and the officer-in-charge then gives the order to start pumping. He usually stations himself on the caisson where he can keep in touch with the ship's officers, see the after sewing and draught marks and the dock water-level marks, and note the general progress of the operation.

If breast shores are used they will have been cut to the required length and marked beforehand. They are then floated in the water to their approximate positions, their heads being adjusted by tackles to coincide with positions chalked on the ship's side, and their heels being kept in position by lanyards until they rest on the dock " altars " (steps).

When the keel of the ship is about two feet off the blocks pumping may be stopped and a diver be sent down to ensure that all is clear. Pumping is then resumed, and when the water is seen to leave the forward and after sewing marks, thus denoting that the full length of the keel is sewed, pumping may again be stopped and the breast shores (if used) finally adjusted and set up ; the shores are set up simultaneously, when ordered by the officer-in-charge, by shipwrights who drive wedges between the heels of the shores and the dock altars. The catamarans are then manned by the ship's company ; they paddle them to

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positions round the ship's side and start scrubbing and scraping the ship's bottom as the water falls. The rate of pumping is adjusted to ensure sufficient time for the bottom to be thoroughly cleaned. As the water level falls the crews should take care that their catamarans do not ground on the propellers, propeller shafts, or dock altars, because a catamaran thus grounded entails reflooding the dock and so wasting time.

As the seacocks for flooding compartments such as magazines and the spirit room are uncovered, their gratings are removed by the ship's engineers, flooding-bonnets are fitted over them, and hoses connected from the bonnets to the dockside hydrants. Pumping may be temporarily stopped to enable this to be done.

When the dock is pumped out dockyardmen cut up and erect any bilge or bottom shores required, while the ship's company sweep the dock-bottom and altars clear of mud and rubbish. The docking tackles are then unrove, and if breast shores are used their head tackles are replaced by lanyards.

The brows are then placed in position and secured, and hoses and cables are connected between ship and shore to provide fresh and salt water, electricity, telephonic communication and earthing arrangements.

Flooding-up

The day before a ship is due to be undocked, and before flooding operations are begun, the *Undocking Certificate* and the *Certificate of Changes of Weight in Dock* must be completed and forwarded by the Commanding Officer of the ship to the Manager of the Constructive Department of the dockyard.

The *Undocking Certificate*, which is signed by the Commanding Officer, contains statements to the effect that the various underwater fittings of the ship, such as seacocks, bottom-logs, asdic domes, submerged torpedo-tubes and their sea connections, are shut and in good working order, these statements being signed by the officers responsible for the fittings.

The *Certificate of Changes of Weight in Dock* is also signed by the Commanding Officer, and contains details of all changes of weight which have been made in the ship while she has been in dock. If any changes are made after the certificate has been forwarded, full details must immediately be forwarded to the Manager of the Constructive Department, and the changes must be approved by him before flooding of the dock is begun.

Before flooding is begun, bottom and bilge shores and any staging are removed, and any arisings are cleared from the dock. Catamarans are secured to prevent them from damaging the ship or themselves when the floodwater rushes into the dock. Hoses and cables carrying shore supplies are either disconnected or slacked off to allow for the rise of the ship in the dock ; all brows, except one which is slung on a crane, are removed ; the docking tackles are re-rove on the fore- and after-guys, and the docking hawsers are passed and rove.

When all is ready the representative of the Constructive Manager, who is in charge of this stage of the operation, gives the order to flood the dock, and the penstocks are opened. As the ship lifts off the keel blocks the docking tackles are worked to keep her in the correct position, and any breast shores used will float clear, their heel lanyards being tended to keep them from fouling obstructions as the water rises in the dock. When the level of the water inside the dock is the same as that outside, the caisson is removed and the docking

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tackles unrove, and charge of the operation is handed over to the representative of the Captain-of-the-Dockyard.

Undocking

The ship is warped to the entrance by the docking springs, which are led aft from the ship to the dockside capstans while the guys are worked to keep her in the middle of the dock. As her stern reaches the entrance tugs are secured and tow her clear, the guys being cast off as ordered by the officer-in-charge of undocking. As soon as the last guy is cast off the manœuvring of the ship is under the charge of the pilot, and he gives the necessary orders to the tugs to tow her to her berth.

Floating Docks

When a ship is docked in a floating dock the disposition of her weight in the dock must be very carefully considered, both to avoid straining the structure of the dock and to preserve its stability. The displacement and trim of the ship, and the distribution of weight in her, must therefore be carefully adjusted beforehand to the requirements of the Constructive Manager.

The ship is placed in the dock so that her centre of gravity lies directly over the centre of buoyancy of the dock. The position of the ship's centre of gravity is obtained from the ship's docking-plans and then indicated by a mark painted on each of her sides, and the position of the dock's centre of buoyancy is marked on each side of the dock.

In other respects the operations of docking and undocking are very similar to those for a dry dock.

Docking Small Vessels with considerable Trim

Vessels such as tugs, trawlers and drifters, whose draught forward differs considerably from their draught aft, require extra care when being docked down. When the after end of the keel touches the keel-blocks the vessel is " pinned " in position by breast shores placed immediately above the point where the keel touches the blocks. The shores are not set up, but are held lightly in position to steady the ship until the keel is sewed for its full length ; then the remainder of the breast shores are placed, and all are set up together.

Docking Destroyers

Particular care is necessary when docking down a destroyer to ensure that her rudder and propellers are not damaged by the keel-blocks. The ship should be trimmed only slightly by the stern, and each propeller should be turned so that one of its three blades is at " 12 o'clock."

Destroyers whose fuel and ammunition have been disembarked are liable to be rather tender, and particular care should therefore be taken to ensure that no weights are moved on board when docking or undocking, and that the *Certificate of Changes of Weight in Dock* has been accurately compiled in every detail.

Docking Submarines

The Commanding Officer of a submarine must first inform the officer-in-charge of docking-down or flooding-up that his ship is in the required state of trim, and during these operations he should not alter the trim without consulting the

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officer-in-charge. Before entering the dock it is usual to blow all main tanks and leave the main tank Kingston-valves open until the ship is docked-down; before flooding-up, however, the main tank Kingston-valves are closed.

Breast shores are placed where the hull is broadest, and as these positions are usually underwater when the vessel is sewed, steadying shores are placed against the casing to keep her upright until the breast shores are in position and set up. Steadying shores are also placed before flooding-up and kept in position until the vessel is fully afloat.

MANŒUVRING IN A CANAL

When a ship is going through a canal her bridge and engine-room staff should be at manœuvring stations, both her anchors should be ready for letting go, she should be steered by experienced quartermasters, and by night a searchlight should be provided in the eyes of the ship to illuminate the canal and both its banks ahead of the ship. If the ship may have to secure to the canal bank during her passage, one or two boats may have to be towed astern to take her hawsers ashore.

Disturbance of the Water and its Effects on the Ship

The effects of shallow water on the speed and steering of a ship, as described on page 64, are intensified in a canal because the movement of the water displaced by the passage of the ship is confined within narrow limits by its banks. This restriction on the flow of the displaced water also produces other effects on the steering of the ship.

The general effect of the passage of a ship through a narrow canal is to raise the water level ahead of the ship and to lower it astern of her, and the bigger the ship and the faster she goes the more marked this will be. The effect may be noticeable over considerable distances, and it is recorded that the surge of water made by a ship proceeding at undue speed in the Manchester Ship Canal parted the hawsers of a ship moored three miles away.

A ship moving along a canal pushes ahead of her a volume of water proportionate to her size and speed, and this displacement of water is manifested in the following manner :— A swell-like wave which travels with the ship is formed across the canal, ahead of and under the bows; a similar but smaller wave which follows the ship is formed across the canal directly astern of her; between these two waves a long shallow trough is formed across the canal, extending from abaft the ship's bows to her stern and deepest a little abaft midway along the ship; in addition, small subsidiary waves are formed which radiate from the bows and quarters of the ship (see Fig. 22).

The displaced water flows outwards from the bows and creates a zone of pressure around them; it also flows strongly into the trough and creates a zone of suction on each side of the ship; each of these zones extends in depth from the surface to the bottom of the canal. The pressure zone tends to repel anything floating away from the bows, and also to repel the bows away from anything solid, such as the canal bank. The suction zone tends to attract any floating thing towards the sides and quarters of the ship, and also to attract the after part of the ship towards anything solid, such as the canal bank. The nearer

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the ship is to one bank of the canal the greater will be the disturbance of the water between her side and the bank and the greater will be the forces of repulsion and attraction on that side, while on her other side the forces will become progressively less the farther the ship is away from the opposite bank.

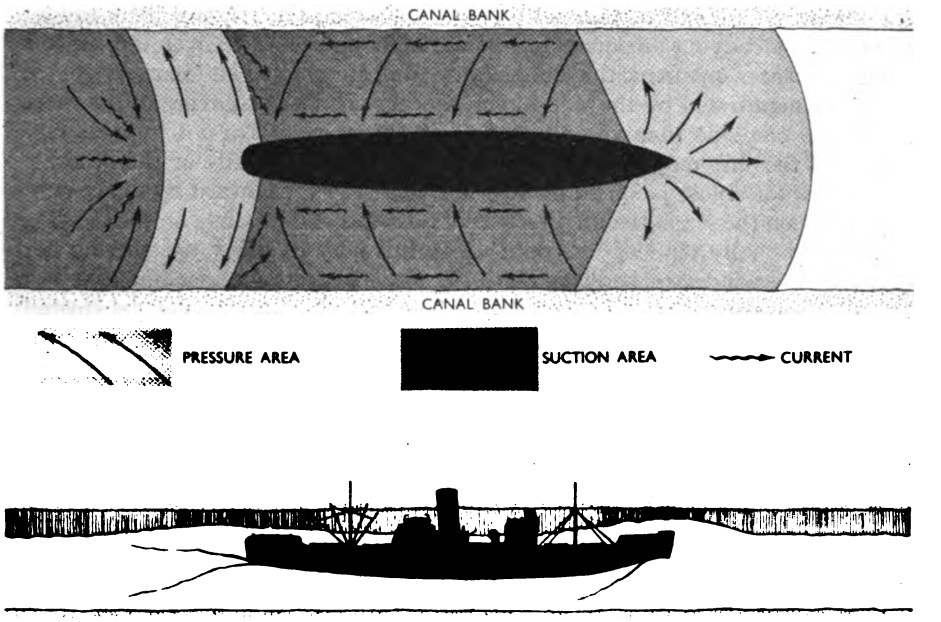

Fig. 22. Zones of pressure and suction caused by a ship moving ahead in a canal

If, therefore, the ship is moving along the centre of a canal of symmetrical cross-section the forces of repulsion and attraction will be equally disposed on each side of her and so they will not affect her steering. But if the ship is nearer to one bank than the other her bows will be repelled from the nearer bank and her after part attracted towards it, thus slewing the ship so that she heads for the opposite bank. As her bows close this bank they will be repelled from it and the ship will be slewed parallel with the bank, then as the after part is attracted towards the bank and the bows are further repelled from it the ship will be slewed still further and head for the other bank. If the ship's rudder is kept amidships this slewing from bank to bank will become progressively more pronounced, until the angle at which the bows approach the banks will become so great that eventually the repulsive force will be unable to deflect the bows and the ship will actually hit the bank.

Steering the ship in a canal

In calm weather a ship is steered as nearly as possible along the centre of the canal, and if the canal is of symmetrical cross-section the forces of repulsion and attraction will be equally balanced on each side of her. Under these conditions the ship should require little rudder to keep her steady on her course, and any rudder movement should be equally divided between port and starboard.

A canal, however, is seldom of symmetrical cross-section throughout its length ; it may be shallower in some parts than in others, one bank may slope

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less steeply than the other, or the channel may be deeper nearer one bank than the other. Such inequalities will necessitate the ship having to carry rudder, or to use more rudder on one side than on the other. If such inequalities are known to extend for any distance the ship should be steered along the actual centre of the channel and not the visual centre of the canal; in other words she should be allowed to take up a course on which she requires little rudder to keep her steady, or an equal amount of rudder on each side, even though this course is nearer one bank than the other. Bad steering or an incorrect course is always manifested by the ship having to carry rudder or having to use more rudder on one side than the other, and if these errors are not immediately corrected the ship may take a violent sheer towards one bank or the other.

Any leeway must be offset by steering the ship to windward by an amount depending on the strength and direction of the wind and its effect on the steering of the ship. Any tendency of the ship to luff may be offset by steering her closer to the windward bank and so bringing into play the repelling effect of the water pressure on her weather bow. The ship should, however, be steered so that she requires little rudder, or an equal amount of rudder on each side, to keep her on her track.

When negotiating a bend the ship should be steered so that she moves along a track nearer the outer bank of the bend. If the bend is entered with the ship at the correct distance from the outer bank she should negotiate it with the rudder amidships, because the water pressure on her outer bow should be just sufficient to swing her round the bend. If the ship is kept to the centre of the canal rudder will have to be used to take her round the bend, and if she develops a sheer towards the outer bank she may not then have a sufficient margin of rudder left to correct it. If the ship's track is nearer the inner bank there will be a grave danger of her developing an uncontrollable sheer towards the outer bank.

More pronounced movements of the rudder will probably be required in a canal than in open water, because its turning power will be reduced by shallow water effects and the slow speed of the ship. The art of steering the ship lies in anticipating any tendency of the ship's head to swing off the course and in taking the necessary corrective action in good time.

Speed of the ship

In every canal a maximum speed-limit is imposed, and the most suitable speed below this at which a ship should proceed depends largely on her draught and beam in relation to the depth and breadth of the canal. The speed used should always be well within the maximum speed of the ship to allow a good margin for use in emergencies. A deeply laden ship with little water under her bottom should proceed at a much slower speed than if she were lightly laden; a lightly laden ship in a beam wind may be unmanageable below a speed at which she would handle well if heavily laden.

The speed of a ship for a given number of engine-revolutions is always less in a canal than in deep water because of the shallow-water effects already described; this reduction of speed is greater when the ship is deeply laden.

A careful watch should be kept on the speed of the ship in relation to the depth and breadth of the canal. If the ship is going too fast the bow and stern waves will grow steeper, the trough will grow deeper and she will settle deeper in the water, and her steering will become increasingly difficult. The ship may

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then slow down suddenly, when the stern wave will overtake her and probably give her an uncontrollable sheer to one or the other bank of the canal.

If it is required to slow down or stop the ship, speed should be reduced very gradually, otherwise the stern wave may overtake the ship. If this happens the rudder will have little or no effect and the ship may take a sudden sheer towards one bank or the other. Before reducing speed quickly care should be taken to see that the ship is in the centre of the canal and her rudder amidships when her engines are put astern ; she will then have plenty of room and full use of her rudder to correct a sheer towards either bank.

Correcting a Sheer

One of the most frequent causes of a sheer is too rapid a reduction of speed after going too fast. A sheer may also result from bad steering or steering an incorrect course, or it may be caused by a sudden shoaling of the bottom or inequalities in the sides or bottom of the canal.

Quick action is necessary to correct a sheer, and the more violent the sheer the more drastic must be its correction. The action necessary for single-screw ships differs largely from that for twin-screw ships because of the different effects of the propellers and rudder on the steering of each type at moderate or low speeds. A single-screw ship when going ahead at low speed depends for her steering chiefly on the effect of her rudder, and its effect increases with the speed of the ship and the speed of the propeller, but when the engine is put astern the screw-effect of the propeller predominates over the effect of the rudder. In a twin-screw ship at low speeds, ahead or astern, the turning effect of the propellers is usually greater than that of the rudder, and the ship can usually be manœuvred by her propellers alone.

Correcting a sheer in a single-screw ship.—Unless a sheer is violent it can usually be corrected in a single-screw ship by giving her full opposite rudder and at the same time putting the engine to full speed ahead, the speed being reduced again as soon as the sheer has been corrected.

A violent sheer can be corrected by reversing the engines, but care must be taken to choose the right moment. If, for example, the ship takes a violent sheer to port which cannot be corrected by full starboard rudder, her bows will be repelled and her stern attracted as they approach the bank, with the result that the ship will take a violent sheer to starboard. The best way of countering this is to put the engine full speed ahead and the rudder hard-a-port, and then, as soon as the ship's head stops swinging to starboard or just before, to put the engine full speed astern but keep the rudder hard-a-port. The screw-effect of the propeller will stop the stern swinging into the bank, and the ship should then steady up along the centre of the canal and the engines again be driven ahead.

If the initial sheer had been to starboard the foregoing method of countering it would be useless because in the last stage the screw-effect of the reversed propeller would tend to increase the sheer and swing the stern of the ship in to the bank. If the initial sheer is to starboard the best way to counter it is immediately to put the rudder hard-a-port, and as soon as, or just before, the ship's head stops swinging to starboard to put the engine full speed astern. The screw-effect of the propeller will then stop the swing of the stern in to the bank and reduce the swing of the ship's head to port.

Another effective way of countering a violent sheer is to reduce speed and at the same time let go the anchor on the side opposite to the direction of the

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sheer and hold it at very short stay so that it keeps the bows from falling off as it is dragged along the bottom.

A sheer which develops when the ship is moving at slow speed may sometimes be corrected by reducing speed or stopping the engine, or even putting it slow astern, but this is not usually effective at higher speeds.

Correcting a sheer in a twin-screw ship.—In twin-screw ships, particularly those whose propellers extend beyond the sides of the ship, great care must be taken to prevent the quarters or stern of the ship from getting too near the banks, otherwise the propellers may be damaged by fouling the sides or bottom of the canal.

If not very marked a sheer can be countered merely by stopping the engine on the side opposite the sheer and putting on full opposite rudder. As soon as the ship's head starts to swing in the required direction the stopped engine should be driven ahead, and the rudder put the opposite way, until the ship steadies on the required course. If the ship's head swings back too violently after the initial countering action the swing can be stopped by driving the other engine astern.

If the ship is moving at slow speed a violent sheer is best countered by increasing the speed of the engine on the side towards which the ship is sheering, reducing the speed of the other engine or stopping it, and putting on full opposite rudder.

At faster speeds it may be best to give full opposite rudder, drive the engine on the side opposite the sheer full speed astern, and reduce the speed of the other engine or stop it. This action, by reducing the speed of the ship, will reduce the forces set up in the water and make the ship more manageable.

Passing another Ship

In broad and deep canals ships going in opposite directions may be able to pass each other while both are under way, but usually one of the ships must make fast to the bank to allow the other to pass her. In some canals, the Suez Canal for example, the bank is cut away at intervals to form sidings in which a ship can make fast.

Making fast to the bank.—A ship is made fast to a canal bank in much the same way as she is secured alongside a jetty, except that the way of the ship is reduced very gradually to stop her abreast the berth with as little astern movement of the engines as possible. Plenty of time should be allowed for the manœuvre, and it is usual to begin reducing speed when the ship is about a mile from the berth. In a wind, if there is a choice of banks, the ship is usually made fast to the lee bank. An unhandy ship is usually stopped in the centre of the canal and then warped alongside the bank by her hawsers. Easily handled ships can be manœuvred closer to the bank before the hawsers are sent ashore, but great care must be taken, particularly in multiple-screw ships, to avoid getting the stern too near the bank and so endangering the rudder and inshore propellers. Except in a current or strong head wind, two breastropes should be sufficient to hold the ship in her berth.

Effect on the berthed ship when another ship passes.—A berthed ship will surge considerably in the wash of a passing ship, and no hawsers will be able to hold her steady. The berthed ship should therefore be free to move as the other passes her, and her hawsers should accordingly be slackened right off as

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the passing ship approaches. The effects of the passing ship's bow wave, trough, and stern wave on the berthed ship as they reach and pass her are as follows :—first the berthed ship's bows are repelled towards the bank as the bow wave reaches her ; she then surges ahead in the reverse current of the trough and her bows are drawn away from the bank by its suction while her stern is pushed towards the bank by the bow wave ; as the stern wave reaches her bows her movement ahead is stopped, and at the same time her stern is sucked out from the bank by the trough ; finally, as the stern wave passes her stern, the ship surges astern and tries to follow in the wake of the passing ship.

This surging must be controlled by the engines and rudder to prevent the stern from being drawn too far out from the bank and colliding with the quarter of the passing ship, and also to prevent the berthed ship from surging too far astern. The surging can be controlled quite easily by a kick astern and then a kick ahead on the engines, with the rudder put over to the side away from the bank. In twin-screw ships only the offshore propeller should be used.

Course of the passing ship.—The passing ship should approach along the centre of the canal at slow speed, and should endeavour to keep along the centre of the canal as she passes the other ship, even though it entails passing close aboard of her. Even if the course of the passing ship would appear to take her too near the berthed ship, the ships will in fact sheer away from each other, whereas if the passing ship attempts to give the other a wide berth she may then come under the influence of the far bank of the canal and take a sheer towards the berthed ship with perhaps dangerous results.

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CHAPTER VI

Handling Ships in Heavy Weather

HOW BEST to handle a ship in heavy weather depends so much upon the type of ship, and how she behaves under such a wide variety of circumstances, that no rules and only a few generalisations will help to answer this large question. No rule can replace an experienced seaman's sympathetic understanding of his ship's capabilities and his intuitive appreciation of the dangers which beset her, and such understanding can be acquired only by experience and by carefully watching the reactions of different types of ship when in a heavy seaway.

Broadly speaking, there are two different and often conflicting conditions which govern the action a seaman may take in a storm, namely the preservation of his ship from damage, or even loss, and the execution of an important task in spite of the weather.

In the following pages some advice and suggestions, based on actual experience, are offered in the hope that they may help the seaman to decide what action he should take to overcome the particular difficulties which may confront him.

Seas

An unbroken wave is far less dangerous than a breaking wave. In the former the movement of water is mainly up and down, there being comparatively little forward or backward movement, but in the latter a great mass of water is projected with considerable force forward and downward from the crest; furthermore a naturally breaking wave is higher and steeper than its unbroken counterpart. An unbroken wave can, however, be broken by impact with the ship, and its potential danger is then nearly as great as the wave which has broken naturally.

The speed of advance of successive waves and the interval between them is fairly regular, so that their movement can be judged with a fair degree of accuracy. Although there is no factual foundation for the belief that every fifth or seventh wave is larger than its fellows, careful observation has shown that in any sea there is a fairly regular recurrence of groups of large and small waves, in which successive waves gradually build up in size and then gradually diminish; but the period of these cycles and the number of waves in each vary greatly with the type of sea. In any particular sea, however, the cycle occurs with sufficient regularity to enable the seaman to predict with a fair degree of accuracy successive short periods of comparative calm.

The greater the expanse of deep water the higher will be the waves generated by a prolonged gale and the greater will be their length between crests; the longer the wave-length the longer will be the period of the waves and the greater will be their velocity. The period (that is the interval of time between the passage of two successive wave crests past a fixed point) and the velocity of the waves are important, because if in a heavy seaway they synchronise with the speed of a ship and her period of rolling or pitching a dangerous situation is set up, and unless the course or the speed of the ship is altered she may suffer severe damage or even founder.

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Waves running from deep to comparatively shallow water grow steeper and higher and then break up and subsequently re-form into a short, steep sea with breaking waves. If the extent of the shoal water is limited by land a backwash is set up which results in a confused sea with dangerously steep and breaking waves.

A heavy swell caused by a strong and prolonged gale over a large expanse of deep water may travel hundreds of miles without appreciably altering its direction. If it meets seas from a different direction caused by a local gale a dangerously confused sea will result.

Broadly speaking, a short steep sea, or a confused sea, is more dangerous to small vessels than to large ships; and conversely, a long heavy sea is more dangerous to large ships than to small vessels.

Effect of the Waves on the Motion of a Ship

When considering the effect of the waves on the motion of a ship the following terms are used :—

Period of roll.—The time a ship takes to roll from one side to the other and back again.

Period of pitch.—The time the bows of a ship take to rise and then fall to the position from which they rose.

Period of encounter.—The interval of time between the passage of two successive wave crests past an observer in a ship.

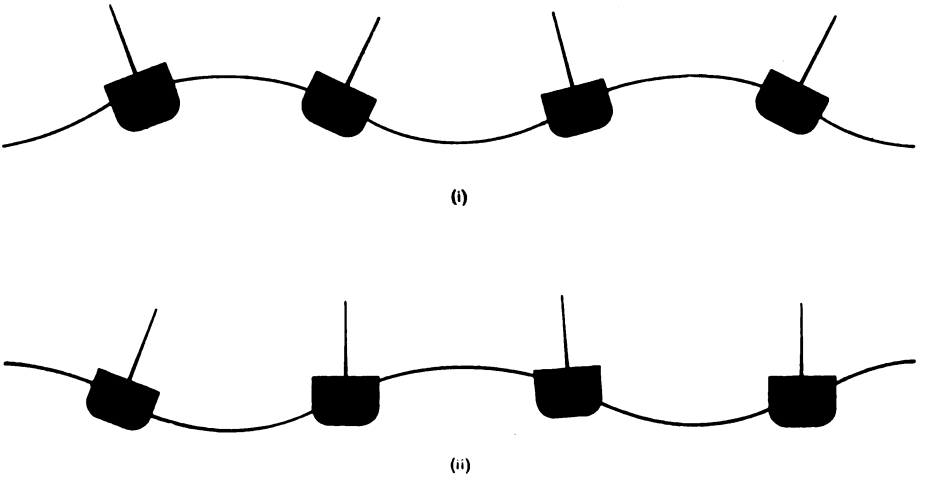

Fig. 23. Effect of the waves on the motion of a ship

A ship's natural period of roll or pitch varies with her degree of stability; a stiff ship will roll more quickly than a tender ship, and a ship with her ends heavily loaded will pitch sluggishly in comparison with one which is buoyant forward and aft.

The way in which a ship reacts to waves depends largely on the angle at which she meets them, and the difference between her period of roll or pitch and the period of encounter.

When a ship is steaming in a beam sea, if her period of roll is small in comparison with the period of encounter, she will tend to lie with her deck

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parallel with the slope of the waves, as shown in Fig. 23 (i); she will then ship little water, but will roll considerably with a rapid and jerky motion which may strain her masts and superstructures. If her period of roll is large in comparison with the period of encounter she will roll slowly and independently of the waves, and to no great angle (see Fig. 23 (ii)); but because she is moving independently of the waves they will break against her side and she will probably ship water. If, however, the period of roll and the period of encounter are the same or nearly the same the ship will roll heavily, and her movement will tend to synchronise with that of the waves; when this occurs the ship may capsize, particularly if her margin of stability is small, unless her course and speed are altered to change the period of encounter.

When a ship is heading into a sea, if her period of pitch is small in comparison with the period of encounter she will not pitch much but will keep her deck parallel with the slope of the waves, and rise and fall with them; in these circumstances she should not ship much water. If her period of pitch is large in comparison with the period of encounter she will pitch slowly and independently of the waves, cut through them or bury her bows in them and probably ship a lot of water, and her propellers may occasionally race. When a ship's period of pitch is about the same as the period of encounter she will pitch violently, her propellers may race frequently, particularly if she is in ballast, and her hull may be seriously strained by the effects of hogging and sagging. If the length of a ship is about the same as the length between successive waves the probability of hogging and sagging will be increased.

The foregoing remarks apply in a modified sense to a ship steaming with the sea on her bow or on her quarter.

The ability of a ship to ride over waves, or steam through them, therefore depends chiefly on her degree of stability, her course and speed in relation to the direction of the waves, and the period and velocity of the waves. It also depends on the length and height of the waves, and to a certain extent on the shape of her hull and its strength in relation to her mass.

Effect of the Wind

The effect of a strong wind on a ship which has been forced to reduce to slow speed depends a lot on her freeboard, her draught, and the area of her superstructures. A lightly-laden ship and a shallow-draught ship will be more affected by wind than a deeply-laden ship. Trim, as already explained in Chapter V, will affect the steering qualities of the ship.

Most ships tend to lie more or less broadside on to the wind, and in exceptionally strong winds it may be difficult to steer them up to windward, though it may be possible to turn them down wind. Some ships, such as low-powered single-screw freighters and ships with high freeboard and superstructures, sometimes cannot be turned head to wind in a typhoon or a hurricane. An example of this occurred in 1949, when warships at Hong Kong put to sea to ride out a typhoon. In a 100 m.p.h. easterly wind, which was tending to blow the ships onto a lee shore, a light fleet carrier, destroyers and " Bird "-class frigates were able with difficulty to claw to windward, but " Bay "-class frigates lay helpless broadside on to the wind because of their inability to turn to windward; luckily, however, none of them was driven ashore.

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Leeway.—The amount of leeway a ship will make in a gale depends on her speed, her draught and freeboard, and on her course in relation to the direction of the wind and seas, but in a whole gale with the wind abeam it can be very considerable, particularly if the ship is steaming at slow speed, and her drift to leeward may then amount to as much as two knots or even more.

It is a common mistake among inexperienced seamen to make insufficient allowance for leeway, particularly in a prolonged gale when, in addition to the wind, there will probably be a surface current set up by the gale. The amount of leeway a ship will make in any particular conditions can only be judged by experience, but a rough estimate can be made by looking aft at the wake of the ship and noting its direction relative to the mean course she is steering.

Handling a Ship in a Seaway

How best to handle a ship in a seaway depends largely on the particular ship, her condition of loading, the weather, and if it is required to make ground to windward, heave to, or drift.

Steaming head to sea.—There are three factors to be considered when a ship is heading into a seaway, namely : the force of impact of the waves on her bows ; the pitching of the ship and the resultant strains of hogging, sagging and pounding ; and waves breaking on board, whether this is caused by their impact with the hull or the pitching of the ship, or both.

The force of impact of the waves varies with the product of the ship's mass and the square of the combined velocity of the ship and the waves, and a small reduction of speed will therefore considerably lessen the force of impact. The larger the area offered to the seas the greater will be the shock of impact, and when ships whose bows are considerably flared, such as aircraft carriers, are pitching, they will be forced to reduce speed sooner than ships with comparatively straight-sided bows. In the Second World War on several occasions the Home Fleet had to reduce speed in a head sea to seven knots for the sake of a fleet carrier, when destroyers were comfortable at 14 knots.

A ship with fine lines and little flare to her bows, such as a " Colony "-class cruiser, will tend to cut through the waves or bury her bows in them, and so will probably be a wet ship when heading into a long sea. A similar ship with an appreciable flare to her bows, however, will not plunge so heavily into head seas because of the extra area of support given by the flare when she pitches ; she will consequently be drier, but may tend to bump heavily.

The trim of a ship may have a considerable effect on her behaviour when steaming into a head sea. If she is trimmed at all by the head, or if she is heavily laden forward, she will probably pitch sluggishly and tend to bury her bows in the waves ; this may lead to dangerous conditions. Conversely, if she is trimmed too much by the stern her bows will tend to pay off to one side or the other, and it will be difficult to keep her on her course heading into the seas. The best condition for a ship steaming into a head sea is for her to be trimmed slightly by the stern and lightly laden well forward, thus ensuring that her propellers and rudder are well immersed and that her bows are buoyant.

An alteration of speed may have a considerable effect on the pitching of a ship because it alters the period of encounter, but a reduction of speed does not necessarily reduce pitching, nor does an increase of speed necessarily increase pitching. After a reduction of speed on account of the weather the heavy ships of a fleet are sometimes more uncomfortable and ship more water than

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do their smaller consorts, and in such circumstances it may be best for the heavy ships to continue at their original speed but to zig-zag, so as to maintain the same speed over the ground as their consorts. Moreover, it is on record that a fast minelayer of some 3,000 tons, built on the lines of a destroyer, was driven safely and comfortably at 31 knots into a short head sea in which speeds of between 16 and 24 knots had proved dangerous.

The decision to increase speed to reduce pitching should, however, be made with caution, because if after increasing it should become necessary to reduce again a dangerous situation may arise if speed cannot be reduced quickly; this should be borne in mind when handling heavy ships which carry their way for a considerable time after reducing the engine revolutions. An increase of speed will also, of course, considerably increase the force of impact of the waves which may seriously strain the hull if the ship is bumping.

When steaming into a head sea, particularly when the distance between successive waves is about the same as the length of the ship, a careful watch should be kept when the ship is heading into the troughs of the seas, because she may then have a tendency to drive her bows under an advancing wave. Should this happen speed should be reduced immediately, otherwise there will be a considerable risk of the whole ship being driven under.

If the propellers are racing excessively the speed or the course, or both, should be altered, otherwise the engines, the propeller shafts and their bearings, and the blades of the propellers may be severely strained. Propeller-racing can be reduced by altering course to bring the sea on the bow or broader on the beam.

Steaming with the sea abeam.—With a beam sea the main considerations are the ship's natural period of roll and the period of the waves. An alteration of speed will have little or no effect on the motion of the ship, but an alteration of course into or away from the sea will have a considerable effect.

A destroyer has a quick period of roll, and when steaming across a short steep sea, though she may keep dry, she may roll so violently that her crew will be unable to keep their feet. Altering course to bring the sea on her quarter will reduce the roll, but because of her low freeboard abaft the forecastle a quartering sea may break on board; she may also tend to yaw because of her shallow draught aft and her small rudder. Altering course towards the sea will reduce her roll and she will steer well, but the force of impact of the waves must then be taken into account, though her high forecastle should lessen the probability of waves breaking on board.

A cruiser may roll heavily in a beam sea because of her rising bottom and rounded bilges, and in such a sea there is often the danger of the period of the waves synchronising with her period of roll. She may also ship a considerable amount of water. Much, however, will depend on the period of the waves, and it is recorded that a small cruiser of some 6,000 tons hove to in a heavy, breaking swell off Ushant, when ordered to rejoin her flagship steamed 200 miles broadside on to the swell at a speed of 23 knots safely, comfortably and without shipping much water. If course has to be altered to avoid synchronisation of her period of roll with that of the waves, or seas breaking on board, a cruiser will usually be steadier and more comfortable with the sea abaft the beam than before it.

In a hurricane a fleet carrier rode very comfortably at a speed of 11 knots with the sea on her quarter.

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Running before the sea.—When running directly before a heavy sea the chief considerations are the steering of the ship, her speed and length in comparison with the velocity and length of the waves, and to a certain extent her type.

The chief dangers to guard against when running before a heavy sea are being pooped, and broaching-to. Pooping may occur when the vessel is in the trough of breaking waves which are moving much faster than the vessel. Broaching-to occurs when the vessel is moving at about the same speed as the waves and when she is on the forward slope of a wave or in its trough. In broaching-to the vessel is slewed violently round broadside to the waves which may thus break aboard her, heel her over, swamp her, and possibly capsize her, and broaching-to is therefore the greater of the two dangers.

Many ships do not steer well when running before a sea, and tend at times to yaw uncontrollably. This applies particularly to destroyers, because of their deep fine entry, shallow flat run and small rudder; it also applies in lesser degree to ships with counter sterns, because a following sea tends to lift the stern and slew the ship round.

If the sea is appreciably longer than the ship she should ride quite comfortably with little danger of " surfing " or being pooped unless the waves are breaking. If the sea is appreciably shorter than the ship she should also ride quite comfortably, though she may pitch more violently and her propellers may occasionally race; but if her speed is considerably less than the velocity of the waves there is a danger of her being pooped. It is when the length of the ship and the length of the sea are the same or nearly the same that the dangers of " surfing " and broaching-to or being pooped are greatest, particularly when the speed of the ship is the same or nearly the same as that of the sea.

In a long, heavy sea a ship will feel the full force of the gale when on the crests of the waves and be comparatively sheltered when in the troughs. When on the forward slope of a wave her speed will increase, but it will decrease in the trough and when on the rear slope of a wave. When on the crest of a wave she will be deeply immersed amidships but have little water under her bows and stern, her rudder will then have little effect and her propellers may race.

If the length of the ship is about the same as that of the waves but her speed is greater, a dangerous situation may arise when she is balanced on the crest of a wave. Her speed may be decreased because her propellers are not fully immersed, and her rudder may be out of the water; she is then helpless and may remain in this precarious position for some time; then when she pitches into the downward slope of the wave she may take a violent sheer and broach-to.

If the length of the ship is about the same as that of the waves and her speed is about the same or a little less, there is a great danger of her " surfing " and broaching-to because she may then be borne forward bodily on the forward slope of a wave with her rudder and propellers out of the water; she may then slide down the forward slope of the wave, bury her bows in the trough, and then probably take a violent sheer and broach-to.

When running before a heavy sea which is about the same length as the ship it is best, therefore, to keep her speed well below that of the waves, but fast enough to give her sufficient steerage-way. There may then be a danger of the ship being pooped, but this can be lessened by timing the period of the waves and altering the speed of the ship accordingly.

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The following account of a 6,000-ton light cruiser running for 30 hours before a whole gale in the Atlantic is of interest.

> " The waves were about 40 feet high and about 1,000 feet from crest to crest, and we found 17 knots about the best speed—slower than the waves but fast enough not to be pooped badly, and a speed at which she did not bury her bows. Early on when the sea was slightly on the quarter a wave carried away the cutter's gripes, but thereafter we kept her dead before the sea and suffered no further damage. Steering was difficult, particularly at night, and required constant supervision by the Officer-of-the-Watch with the quartermasters standing half-hour tricks."

Small vessels, particularly sailing vessels, may be forced to run before a following sea when they may be blown along at a speed approaching that of the waves. In these circumstances they should stream a drogue or the bight of a hawser to reduce their speed and so avoid the dangers of " surfing ".

Whenever you are running before a heavy sea and there is land or shoal water to leeward you should adjust the ship's course to pass well clear of shoals and shallow water, because in these areas there will probably be dangerously steep and confused seas.

Turning in a seaway.—To turn in a really heavy sea requires good judgment and a thorough knowledge of the handling qualities of your ship. Experienced seamen are agreed that you must choose the right moment to turn in a heavy sea, and that you must then turn as quickly as possible, but without too much headway on the ship. The recurrent cycle of large and small waves must be observed carefully so that the turn or part of it can be made in a comparatively calm period, and full use should be made of the turning powers of the rudder and propellers.

If you are hove-to head to sea and you want to turn and run before it, you should watch the sea and start turning just before the arrival of a relatively calm period, so that the ship will be beam on to the sea when it arrives. The first half of the turn should be executed under full rudder and with short bursts of the engines, but without gathering much headway ; then complete the turn as quickly as possible.

If you are running before the sea and want to turn head on to it you should slow down, watch the sea for your opportunity to turn, and put the wheel over so that the last half of the turn will be made in a comparatively calm period. The first half of the turn should be carried out with as little headway as possible, and the turn then be completed as quickly as possible, if necessary with bursts of full engine, but without gathering much headway.

Although it is necessary to reduce your headway as much as possible when turning, care should be taken never to gather sternway into a sea because you may then be pooped, and the impact of the seas may severely damage your rudder and propellers.

Heaving-to.—When you have to heave-to because of the weather your chief concerns must be to keep your ship as steady as possible and to prevent seas breaking on board and damaging or flooding her.

Broadly speaking, a ship may be hove-to in any of the three following ways :—

(i) by lying with the sea on the bow and steaming ahead at the minimum speed consistent with steerage-way ;

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(ii) by lying with the sea on the quarter and steaming ahead at the minimum speed consistent with steerage-way ;

(iii) by lying with the ship stopped and allowing her to drift to leeward.

The choice of method depends largely on the type of ship and her degree of stability, the condition of the sea and the amount of sea-room available.

The first method is suitable for a ship with a long, high forecastle, because it provides a certain amount of protection from breaking seas, and it is the usual method adopted in cruisers and destroyers. When sea-room to leeward is limited it has the advantage that the ship does not lose ground and may even gain it, though slowly. Its disadvantage is that the impact of the waves is not reduced to a minimum, and in a short, steep sea the ship may pitch and pound heavily.

The second method requires plenty of sea-room to leeward, and the ship must handle well at slow speed with the sea on the quarter. The ship will not tend to pitch so heavily, and the impact of the waves will be reduced to a minimum. Aircraft carriers and merchant ships have been hove to comfortably in this way when the first method has proved impracticable because of heavy pitching and pounding. Its disadvantage is the danger of the ship being pooped.

The third method also requires plenty of sea-room to leeward because in a whole gale the ship may drift at a speed of two knots or more. It is a method which has been used with success in merchant ships, particularly low-powered freighters which cannot be turned head to sea and which are unmanageable at slow speeds with the sea astern or on the quarter. With this method the impact of the waves is considerably reduced, but because the ship will lie more or less broadside on to the seas this method should not be attempted in a stiff ship because such a ship will then roll heavily, her hull may be strained and her cargo may shift.

No advice on which method to adopt can be given because so much depends upon the way in which different ships will behave, and upon the particular weather conditions at the time. This can be illustrated by the following factual examples :—

(*a*) " An aircraft carrier and her attendant destroyer were hove-to in the Bay of Biscay in a gale of ' storm ' force, and in a very high, steep and confused sea. The carrier steamed at revolutions for seven knots with the sea on her bow, pumping oil on the water for the sake of the destroyer which kept station about two cables on the carrier's lee quarter. At the height of the storm the carrier was pitching and pounding heavily with seas breaking over her flying deck ; but the destroyer, an ' S ' class vessel of some 900 tons, built in 1918, was riding quite comfortably and drily, heaving up and down like a cork. Sixty miles away a large, well-found freighter foundered with all hands when lying in the trough of the waves after her engines had broken down."

(*b*) " Two cargo liners of the same class, on the same route and owned by the same company, were overtaken in the Bay of Biscay by particularly bad weather. The engines of one broke down and she drifted helplessly beam to sea in the trough of the waves, but she rode out the gale safely, her engines were repaired and she continued her voyage. Her sister ship some miles away foundered at the height of the storm when hove-to steaming slowly head to sea."

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(*c*) " In a destroyer of 1,500 tons which operated in many Atlantic gales during the Second World War the following general rules were found useful :—

(i) The ship could run comfortably before the sea at a speed of from ten to twelve knots, but at a higher speed there was a tendency to broach-to. When running she rode best with the sea slightly on one quarter.

(ii) When running before a gale the height of the swell was carefully noted, and when it appeared to be higher than the bridge it was usually advisable, and more comfortable, to turn and heave-to with the wind about two points on the bow. After turning, the engine revolutions were kept at a speed corresponding to about nine knots, the speed being increased temporarily if the ship showed a tendency to fall off her course. When hove-to at nine knots the ship did not pound too badly, and steerage-way could usually be maintained."

Common mistakes.—It has been emphasised that no rules and few generalisations can be made for handling ships in heavy weather, but much can be learnt from the mistakes of others.

The following are some of the more common mistakes made by inexperienced seamen which have resulted in severe strain to the hull of the ship and severe damage to her upperworks :—

Driving a ship too fast into a head sea ; particularly a fast, lightly built ship such as a destroyer.

Failing to reduce speed soon enough in a head sea or swell through being unable to visualise the consequences, or fear of being considered too cautious.

Running too fast before a following sea, particularly when the length of the ship and of the sea are about the same.

Failing to alter course in a beam sea to break the synchronisation of the period of the waves with that of the ship's rolling.

Failing to appreciate the signs of an approaching tropical storm and so not taking the necessary action in time to avoid it.

Failing to make the ship as seaworthy as possible before the approach of a storm.

Avoidance of Revolving Tropical Storms

Whenever possible the seaman should give a wide berth to a hurricane, cyclone or typhoon, because these revolving storms, especially their centres, are so violent that small ships may well founder in them and large ships be seriously damaged. Action to avoid such storms should be taken in good time because once the wind and sea start to rise they usually increase so rapidly that the ship may soon become unmanageable and unable to steer a course for safety. The methods of foretelling the advent of a tropical storm, of determining its probable position and course, and the rules for avoiding it are to be found in the first part of each volume of the *Admiralty Sailing Directions*, and these should be studied by every seaman.

Making the ship Seaworthy

When a ship is about to encounter heavy weather she should be made as seaworthy as possible before the sea gets too rough. This might appear obvious,

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but there are many instances of ships foundering through failure to take elementary precautions to increase the stability of the ship, such as by pumping, flooding or ballasting, or jettisoning deck cargo. It is emphasised, however, that any measures involving pumping or flooding should be taken in good time and while the ship is fairly steady, because during the process her stability may be seriously compromised by off-centre loading or by free-surface effects of liquids in partially filled or half-empty tanks.

Consideration of the Crew

When considering the course of action to take when faced with heavy weather, the ability of the crew, particularly the engine-room staff, must be taken into account. Although a ship may be quite seaworthy and manageable by her seamen, she may be immobilised by the inability of her engineers and stokers to carry out their several duties because of inexperience, sea-sickness or the violent motion of the ship. Some ships have been lost and many jeopardised from the failure of those in charge to make due allowances for any failure of the human element.

Use of Oil to Calm the Sea

Oil spread in small quantities on the surface of the sea will prevent the waves breaking and damp down the effect of the wind in whipping up the waves into sharp crests. It will not, however, reduce a swell, and its value lies in lessening the probability of shipping water in a heavy, breaking sea.

Good results can be obtained from any type of oil, but animal or vegetable oils are more effective than mineral oils, and heavy oils are better than light oils. In cold weather the oil should be warmed to decrease its viscosity.

The methods of spreading the oil, either through scuppers or soil-pipes, or by means of oil-bags or canvas hoses, are described in the chapter on " Towing," on pages 139 and 140.

The following brief rules should serve as a guide to determine the most effective way of distributing the oil in certain circumstances :—

When running before the sea distribute the oil from the bows by means of oil-bags or through the forward soil-pipes. The oil will thus spread aft and give protection from seas from right astern and from the quarter. If it is only distributed from the stern there will be no protection from quartering seas.

If yawing badly, distribute the oil from the bows and from both sides amidships. If it is only distributed from the bows the weather quarter is left unprotected when the ship yaws.

Oil will probably be ineffective if the ship is going at more than about four knots through the water.

When heading into the sea the oil should be distributed from as far forward as possible on both sides. Oil-bags slung over the bows will probably be tossed back on deck by the waves, but it is recorded that a small destroyer of some 550 tons displacement overcame the difficulty successfully by rigging a spar as a bowsprit and running out an oil-bag to its end by means of a messenger.

When steaming with the wind and sea abeam the oil should be distributed through soil-pipes and scuppers from the weather bow and the weather side

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amidships.

When hove-to bow to sea, or drifting with the wind and sea abeam, the oil should be distributed through soil-pipes and scuppers, or by oil-bags spaced at intervals of 40 to 50 feet along the weather side.

When at anchor the oil should be distributed from oil-bags hauled out ahead of the ship by means of a messenger rove through a tail-block hitched to the cable.

Blizzards

A danger in blizzards is the formation of ice on the weather decks, superstructures, masts, yards and rigging of a ship. Ice forming anywhere but on the decks presents little danger because it will probably fall away of its own accord before it reaches noticeable proportions. Ice forming on the decks, however, is a different matter because here it will accumulate rapidly and its additional weight so high in the ship may seriously affect her stability.

The only effective method of getting rid of such ice is to cut it up with crowbars and axes into manageable chunks and then lever these over the side.

Steam hoses have been used on ice, but in very cold weather they will not be effective because the steam will merely condense and then freeze, thus forming more ice.

Sea Anchors

Much has been written about the effectiveness of sea anchors in keeping a vessel head to wind and sea and reducing her rate of drift to leeward, but most of this advice was given in the days of sail when vessels were equipped with heavy wooden spars and stout canvas sails which were eminently suitable for making a sea anchor of effective size. It is doubtful whether a sea anchor of sufficient size to hold any but very small vessels can be constructed with the materials available in the average steamship of today (1954).

In shallow water a ship has been kept head to wind and sea by unshackling her anchor, veering a long length of the cable, and trailing it along the bottom. This method may trim the ship by the head, and if it is used arrangements should be made to slip the cable immediately should the necessity arise.

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CHAPTER VII

Towing at Sea

NO STANDARD method of towing or being taken in tow can be laid down because the method by which one ship tows another depends largely on the types of ship involved, the condition of the towed ship, the duration of the tow, and such other matters as the urgency of the situation, the weather and the route to be taken.

The description given here of towropes and methods of securing them, and of methods of towing which have proved successful in practice, should, however, enable the seaman to select the gear and method best suited to the particular towing problem with which he is confronted.

Towropes

Composition

Wire rope is chiefly used for towing because it is neither so bulky nor so heavy as cordage of similar strength, and is therefore more easily stowed and handled. It possesses very little elasticity, however, and will part if suddenly subject to a stress which, if applied gradually, it would have withstood with ease. Towropes are therefore usually of a composite nature to provide them with the required degree of elasticity or springiness. Elasticity is provided by incorporating a length of cable-laid manila of approximately the same strength as the wire rope ; and springiness is provided by incorporating a length of chain cable which, though inelastic, by reason of its weight acts as a spring and so absorbs sudden stresses.

For ocean towing by tugs not provided with self-tensioning winches the towrope is usually composed of manila rope, wire rope and chain cable, but for emergency tows it is quickest and simplest to use a wire hawser shackled to a suitable length of the towed ship's anchor cable. For emergency tows at short stay, such as towing a burning vessel clear of shipping in harbour, the hurricane or spring hawser described in Volume II of this manual probably makes the most efficient towrope.

Strength

The required strength of a towrope depends upon the power available in the towing ship, the intended speed of towing, and the displacement of the towed ship. A rough rule for estimating the towing power of a tug fitted with reciprocating engines is to allow a pull of one ton for every 100 units of indicated horse-power ; thus a vessel of 2,000 I.H.P. can be expected to exert a maximum pull of 20 tons in good weather. The forces required to tow various types of warships and freighters in calm weather at various speeds can be found from the graph in Fig. 24. These forces will be greatly increased in rough weather, in a heavy swell, when the towed ship yaws badly or is damaged, or if the ships' bottoms are heavily fouled ; a 60 m.p.h. gale, for example, would increase by some 25 tons the pull required to tow a cruiser. It is emphasised that the tonnage shown in the graph against the freighters is displacement tonnage at deep-load draught, and not gross tonnage. It will be noticed that a lesser towing pull is required for freighters than for cruisers of similar displacement ; this is

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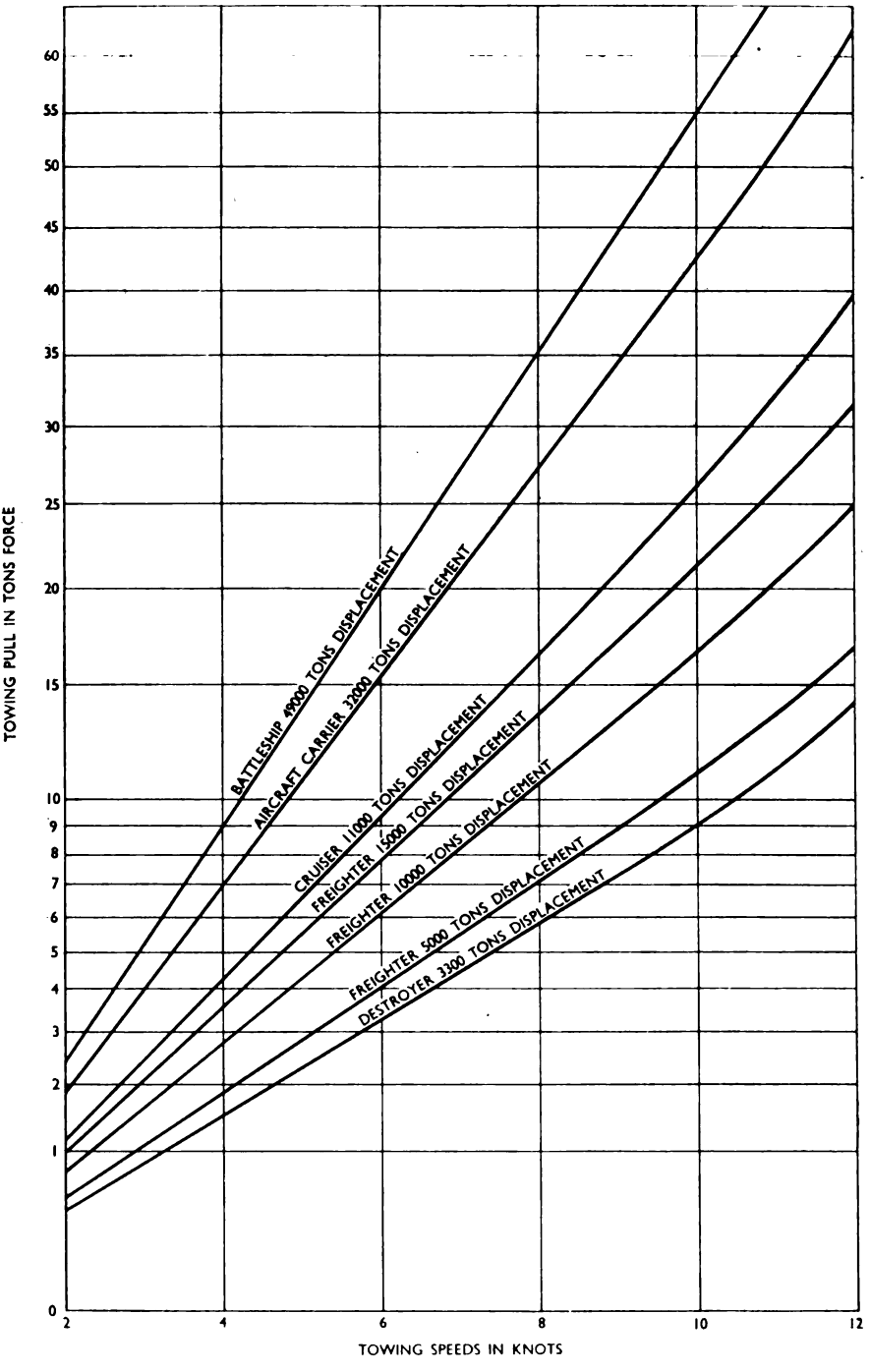

NOTE:

(1) THESE CURVES ARE FOR CALM WEATHER AND FOR SHIPS 3 MONTHS OUT OF DOCK TO ALLOW FOR FOULED BOTTOMS. BAD WEATHER OR YAWING, INCREASE THE FACTOR OF SAFETY.

(2) THE TONNAGE SHOWN AGAINST FREIGHTERS IS THEIR DISPLACEMENT TONNAGE AT DEEP LOAD DRAUGHT AND NOT THEIR GROSS TONNAGE

Fig. 24. Type of ship, towing pull, and towing speed

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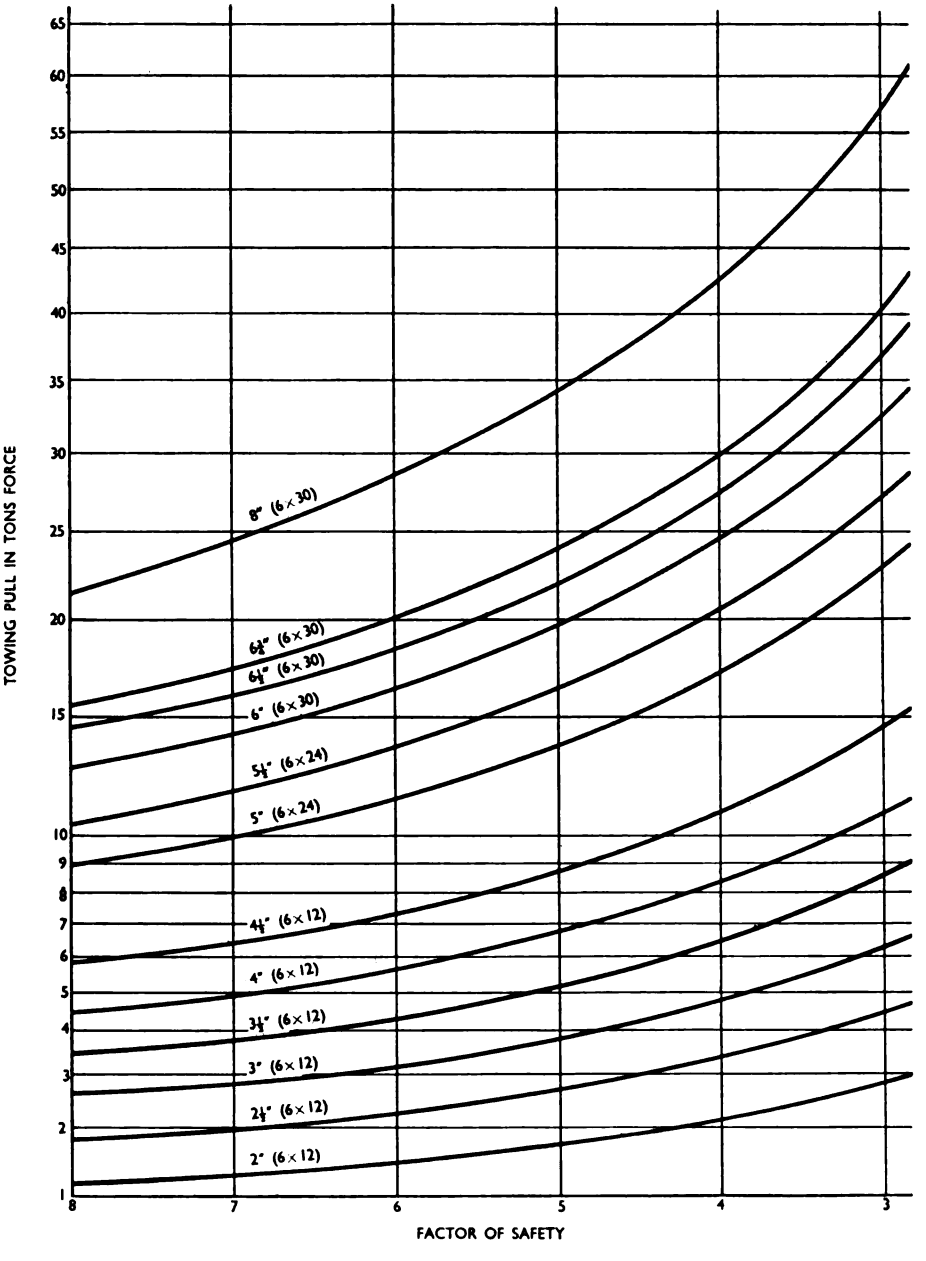

Fig. 25. Towing pull and factor of safety for F.S.W. rope

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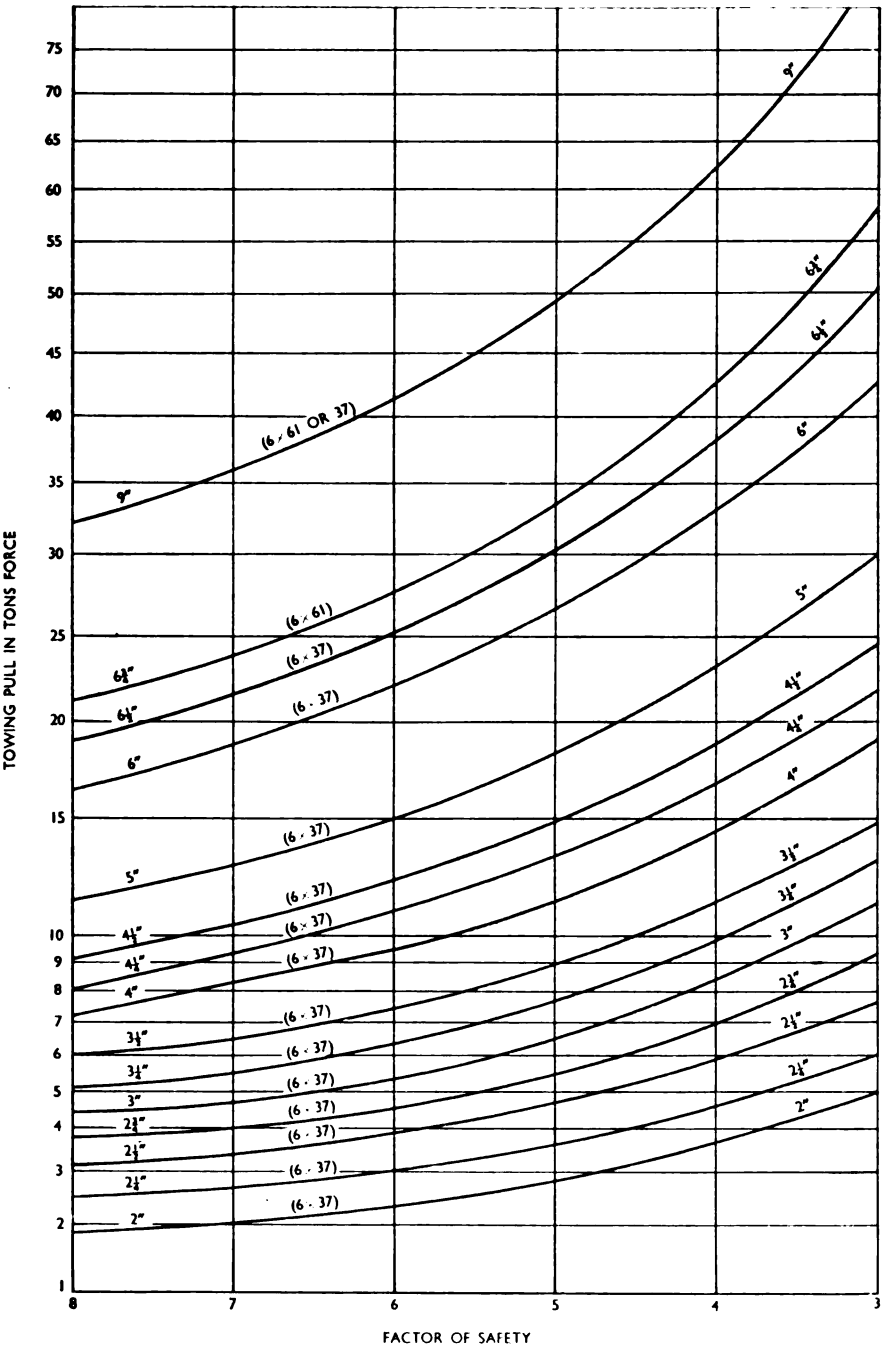

Fig. 26. Towing pull and factor of safety for E.S.F.S.W. rope

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due to propeller-drag, a cruiser having four large-bladed propellers, whereas freighters have usually one, or at the most two, small-bladed propellers.

SELECTION

The choice of towrope depends upon the pull required and the factor of safety it is intended to use. The factor of safety in turn depends upon the gear available and such circumstances as the duration of the tow, the weather, and the urgency of the situation, but it is recommended that it should be not less than four. The graphs in Figs. 25 and 26 show, respectively, the sizes of F.S.W. rope and E.S.F.S.W. rope which are required for various pulling forces using various factors of safety. With these graphs and the graph in Fig. 24, the seaman who has at his disposal unlimited towing power and choice of gear can select the type and size of towrope to suit his particular requirements, and conversely, the seaman with limited resources can estimate the safe capabilities of the gear available.

LENGTH

The length of towrope to be used depends upon the sea room available, the depth of water, the displacement of the towed ship, the required speed of towing, the factor of safety used, the weight of the towrope, and the weather. The chief requirement in towing is to ensure that when the ships are moving at the required speed there is a sufficient sag in the bight of the towrope to absorb any sudden extra stresses. The amount of this sag depends upon the pulling force exerted and the length and weight of the towrope, and the lighter the towrope the longer it must be. The sag must not be too great because not only may the bight then foul the bottom, but the towing ship will have to exert an additional pulling force to drag the bight through the water and also support its weight. For this reason, and because the ships are then more manœuvrable, a short, heavy towrope is preferable to a long, light one.

The graph shown in Fig. 27 gives the length of wire hawser necessary in calm weather to obtain a required depth of sag in the bight. Having determined this depth and the factor of safety, and having selected the type of hawser for the job, the appropriate curve in the graph is taken and the required length of towrope is read off the scale along the bottom.

The graph shows the length of towrope required if using F.S.W. or E.S.F.S.W. rope only; but because the usual practice is to use a composite towrope of chain cable and wire rope, the length shown by the graph can be reduced by an amount corresponding to the length of chain cable veered, and still maintain the bight of the towrope at the required degree of sag. The length by which the towrope can thus be shortened is given by the formula:—$L = k\frac{c}{d}(H-h)$, where:—L is the length of cable to be veered in fathoms; H is the length of towrope in fathoms shown by Fig. 27; h is the length in fathoms of hawser available or required; c is the circumference of the hawser in inches; d is the diameter of the cable in inches; and k is a constant which is 0·11 for F.S.W.R., and 0.13 for E.S.F.S.W.R.

In rough weather a deeper bight is necessary to absorb the sudden stresses to which the towrope will be subjected, and this is better obtained by veering cable than by veering the hawser. The amount of cable to be veered can be obtained from the graph and using the above formula. It is recommended that the bight of the towrope should be immersed to a depth of at least 4 fathoms in calm weather, and at least 6 fathoms in rough weather.

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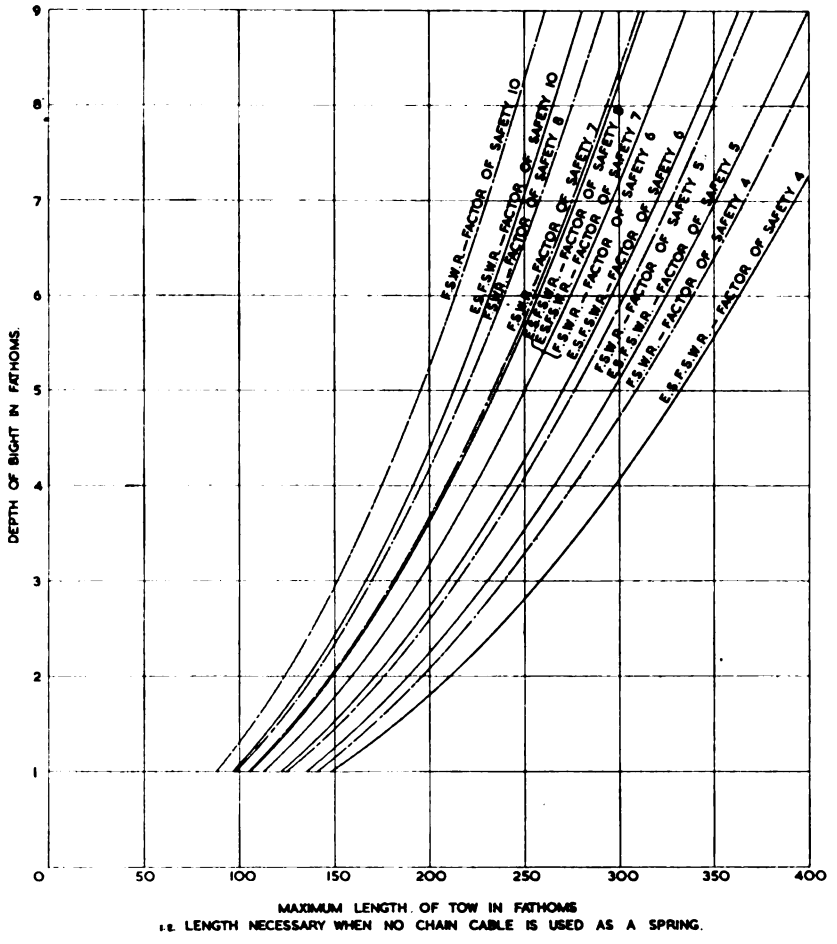

Fig. 27. Dip of tow-rope in relation to length of tow at known factors of safety

How to use the Graphs

The following examples show how the graphs are used to determine the length and composition of the towrope for a particular towing problem, and the probable safe speeds of towing.

It is required to tow a deeply laden freighter of about 5,000 tons deep-displacement, for which the freighter's anchor cable of 2-in. wrought iron and a 150-fathom 4-in. F.S.W. hawser are available. What should be the length and composition of the towrope, and what will be the maximum speed of towing in calm weather ?

From Fig. 25 it is found that a 4-in F.S.W. hawser can take a towing pull of $8\frac{1}{2}$ tons using a factor of safety of four, or a towing pull of $6\frac{3}{4}$ tons using a factor of safety of five, or a towing pull of $5\frac{3}{4}$ tons using a factor of safety of six.

The factor of safety used and the speed of towing will depend upon the urgency of the situation, the probable duration of the tow, and the weather. Assuming that the situation is urgent, that the freighter must be towed at

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the maximum practicable speed for about 30 miles, that the sea is calm and that the weather forecast is good, it would be reasonable to use a factor of safety as low as four. From Fig. 24 it is found that a towing pull of 8½ tons will give a towing speed of about 8½ knots.

The lower the factor of safety used the longer must be the towrope to ensure a good depth of bight. As the sea is calm it would be reasonable to allow for the bight of the towrope to be submerged to a depth of 4 fathoms, to which must be added the mean height above water level of the ends of the towrope, say 2½ fathoms. From Fig. 27 it is found that with a depth of sag of 6½ fathoms and a factor of safety of four for F.S.W.R. the length of wire hawser required would be 350 fathoms. This length can, however, be reduced to 150 fathoms (the length of hawser available) if three shackles (45 fathoms) of the freighter's anchor cable are used as part of the towrope.

Reducing the speed of towing will increase the factor of safety and increase the depth of sag in the bight of the towrope. If the ships are in shallow water or if they have to pass over a shoal patch there may then be a danger of the towrope fouling the bottom and parting. To avoid this the towrope must be shortened, and the graphs and the formula can be used to determine the length and composition of towrope required to maintain the original depth of sag and factor of safety at the new speed of towing.

If, for example, the speed of towing is reduced to 6 knots, reference to Fig. 24 shows that the corresponding towing pull is reduced to 4 tons. On referring to Fig. 25 it is seen that with this reduced towing pull the factor of safety for a 4-in hawser is increased to over eight. By referring to Fig. 27 it is seen that with a factor of safety of eight a 250 fathom length of hawser is required to maintain a sag in the bight of 6½ fathoms, and that this length can be reduced to 100 fathoms by using 35 fathoms of the freighter's cable. In practice, however, it may be simpler to adjust the length of tow by heaving in or veering the cable in the towed ship than by heaving in or veering the hawser in the towing ship, and in this example the same effect is achieved if the freighter heaves in 23 fathoms of cable, thus making a towrope comprising a 150 fathom length of 4-in hawser and 22 fathoms of cable, this being equivalent to a towrope comprising 100 fathoms of hawser and 35 fathoms of cable.

Summary

The chief requirements for towropes may be summarised as follows :—

(i) the towrope should be long enough and heavy enough for a large part of the bight to be immersed when towing at the required speed ;

(ii) when determining the proportion of cable to hawser in a composite towrope, remember that the larger the proportion of cable the better will be its spring ;

(iii) remember, also, that the larger the proportion of cable the shorter will be the required length of towrope, and the shorter the length of towrope the more manœuvrable will be the ships ;

(iv) the rough rule for determining the proportions of cable and hawser used to provide a towrope of a certain weight, is that cable if steel is about five, or if wrought iron about seven, times as heavy as wire rope of approximately the same breaking strength ;

(v) a good rough rule for towing in moderate weather is : " use three

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shackles (45 fathoms) of the towed ship's anchor cable shackled to 150 fathoms of wire hawser of a size of about two-and-half times the size of the cable ; with a 2-in cable, for example, use a 5-in hawser."

Connecting and Securing the Towrope

Connecting-links

Lugged anchor shackles should always be used as connecting-links in towropes, because they are long enough in the clear to take the eyes of the hawsers, they will pass through fairleads and hawsepipes and over obstructions without opening or being damaged, and they are positively locked by their pins and pellets. It is important to ensure that the shackles are as strong as the hawsers or cables with which they are used.

If an anchor shackle of suitable size and strength is not available a grommet strop should be used as a connecting-link. (The construction and strength of a grommet strop are described in Volume II of this manual.)

Swivels are useful but not essential in a towrope, except that with a hawser-laid manila towrope a swivel at each end is necessary. When a swivel is inserted in a composite towrope the best place for it is between the cable and the wire hawser.

Prevention of Bad Nips

Hawsers and cables should be given as fair a lead as possible, and any semblance of a bad nip should be corrected by using pad-pieces or bolsters of metal or hardwood. Hawsers should not be belayed to bollards having a diameter of less than four times the size of the rope. Cable, because of its construction, is more susceptible to injury from a bad nip than is wire rope and therefore requires bollards of larger diameter than wire rope of equivalent breaking strength ; cable should not be belayed to bollards having a diameter of less than twenty times the size of the cable. A ship's bollards are usually designed to take only her berthing hawsers, and her bollards are therefore usually too small for her cable ; if her cable has to be connected to a pair of her bollards it is best done with a bollard strop and shackle.

Eliminating or Reducing Chafe

It is most important to prevent the towrope from chafing, or reduce the effects as far as possible, where it passes through fairleads or hawsepipes. Hawsers should be parcelled with any hard-wearing materials such as canvas and coaling bags, or be served with rounding or junk. Fairleads and hawsepipes should be lined with softwood covered with canvas or burlap, and grease or soft soap should be used liberally to minimise any chafe. Cable withstands chafing better than wire rope and is not therefore usually parcelled, but it should be kept well greased. Whenever practicable, arrangements should be made to freshen the nip of a hawser or cable. The nip of a hawser requires freshening more often than that of cable. The intervals between freshening the nip depend upon the amount of chafing experienced ; in calm weather the nip of a cable is usually freshened every 24 hours, and that of a hawser between every four and eight hours.

The standard towing arrangements provided in a warship do not allow for the nip to be freshened. A destroyer tows from a special slip fitted to her stern, and the nip of her towrope does not therefore require to be freshened. A cruiser tows from her after bollards, the end of the towing-pendant being shackled to

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a deck-clench ; this arrangement can, however, be modified to allow the nip of the hawser to be freshened by leading the hawser from the towing fairlead round the after barbette and thence to the bollards, as shown in Fig. 28.

A battleship tows from her after barbette, the towing-pendant being led once round the barbette and the end shackled to a deck-clench just before it. This arrangement can be modified in the same way as in a cruiser to allow the nip of the hawser to be freshened.

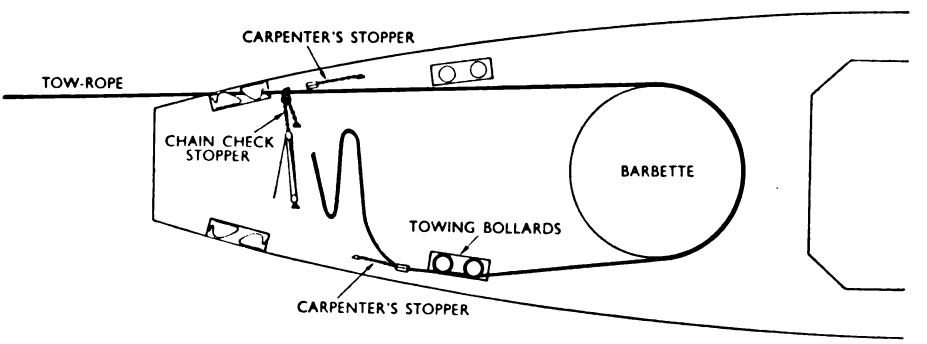

Fig. 28. Lead of towrope in a cruiser to allow the length of tow to be altered or the nip to be freshened.

Strengths of Fittings

The table below gives a comparison between the strengths of the various fittings and equipment used for towing in each class of warship ; the strength of the largest towing hawser supplied to the ship is taken as the unit.

	TOWING HAWSER	BOLLARDS ON F.X. AND A.X.	FORWARD CAPSTAN	CABLE-HOLDER OR WINDLASS	SLIP-STOPPERS AND COMPRESSORS	AFTER CAPSTAN
BATTLESHIP	1	1·5	1·4	1·4	0·5	0·8
AIRCRAFT CARRIER ..	1	2·8	2·1	2·1	0·5	0·9
CRUISER ...	1	3·0	1·6	1·6	0·5	0·4
DESTROYER...	1	1·6	0·7	1·8	0·5	—
FRIGATES ...	1	1·2	—	1·2	0·9	—

The windlass of a merchant ship is usually a little stronger than her cable, and her forecastle bollards are slightly weaker. Her guillotine, if fitted, should be stronger than her cable, and her devil's claw, or other cable stopper, is probably about one-third the strength of her cable.

Before subjecting a pair of bollards to a heavy stress its anchorage should be inspected, and if necessary it should be stayed by a well set-up guy led from the bollard farthest from the source of strain to a deck-clench or other firm anchorage.

The ability of a bollard, capstan, windlass, or cable-holder to withstand the heavy stresses involved in towing depends largely on the strength of the deck

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to which it is fitted, and in small vessels or craft the deck may not be strong enough. In such vessels the towrope must be secured so that the towing stresses are distributed among as many strong fittings as possible, or the vessel must be towed by a girdle rove round the hull and stopped to the gunwale.

The base of a deckhouse, or a superstructure, the coaming of a cargo hatch and the base of a strongly stepped and robust mast or a Samson-post are probably the strongest anchorages for a towrope to be found in a ship, but it may be difficult to arrange a satisfactory lead for the towrope to such anchorages unless the ship is flush-decked.

Securing the Towrope in Ships

For emergency tows the simplest and best method is to use one towrope comprising a wire hawser shackled to one of the bower cables of the towed ship. This arrangement, which was commonly used in the Second World War, allows the towed ship to freshen the nip by simply veering or heaving in cable, and leaves her with one anchor and cable ready for letting go in an emergency.

For prearranged tows some seamen prefer to tow by a single towrope shackled to a bridle made from the two bower cables of the towed ship. If the towed ship can be steered in the wake of the towing ship the towing stresses will be divided between the two legs of the bridle; but if, as often happens, the towed ship rides at a steady angle of sheer to one side or the other of the towing ship's wake, one leg of the bridle will take most of the stress. A short bridle is not recommended because one leg or the other will be subjected to an unfair stress or a bad nip if the towed ship yaws or takes a sheer to one side. Correcting a sheer by shortening one leg of the bridle, as is sometimes done in harbour towing, is also not recommended because that leg will then be subjected to very heavy stresses and probably a bad nip.

Except for emergency tows, or tows of short duration, it is better to lead the cable through the towed ship's hawsepipe than through her bow fairlead, because with the towrope in its normal catenary the fairlead is liable to subject the cable to a bad nip.

Leading the cable through the hawsepipe, however, entails the removal and stowage of the anchor. For prearranged tows this is a simple matter, but for emergency tows it will probably entail jettisoning the anchor, and the decision whether to do this or risk the bad nip in the fairlead must depend upon the circumstances of the tow.

A warship is towed normally from her cableholder or windlass, and the cable is secured by putting on the brake of the cableholder or windlass and then putting on the riding-slip or the compressor, so that the pull of the towrope is taken by the brake, and the slip or compressor acts as a preventer. In ships not provided with a riding-slip or a compressor the Blake-slip is put on as a preventer. In merchant ships fitted with a guillotine the towing pull is taken by the brake of the windlass, and the guillotine is used as a preventer.

If the cableholders of a warship are damaged she should be towed from her capstan if it is fitted to take cable. If a ship's windlass is damaged she should be towed on a bridle consisting of two legs of chain cable; the outboard ends of the legs should be joined by a towing-shackle or an anchor-shackle, and the inboard ends be secured to the forecastle bollards on each side by means of wire rope pendants or bollard strops.

If a ship has to be towed stern first it is best to tow her by a chain bridle with

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the legs secured to the quarter-bollards by wire rope pendants or bollard strops.

For an emergency tow of short duration, such as towing a burning ship clear of a harbour, it is best to use a hurricane- or spring-hawser, or the largest berthing-hawser available, and to secure it to the towed ship by placing its eye over the flukes of one of her bower anchors.

If a towing-hawser is belayed to bollards it is best to use two pairs of bollards on the same side of the ship. A chain-check-stopper should be rove on the towing side of the leading pair of bollards, and a bollard strop with a Carpenter's stopper attached should be placed over the leading bollard of the backing-up pair. The hawser is belayed by taking a round turn round each bollard, and then well-racked figure-of-eight turns round the backing-up pair of bollards. With this arrangement the towing stresses are fairly divided between each pair of bollards, and the hawser will be completely under control when rendering it to freshen the nip, or paying it out to lengthen or slip the tow.

If only one pair of bollards is available the bollard strop with the Carpenter's stopper should be placed over the bollard nearest the source of strain, and the chain-check-stopper should be rove on the towing side of the Carpenter's stopper. The hawser should be belayed by taking a round turn round the bollard nearest the source of strain, then two round turns round the other bollard, and finally well-racked figure-of-eight turns round both bollards. To render or pay out the hawser the Carpenter's stopper is put on, the figure-of-eight turns are taken off, and an extra round turn is taken round the bollard farthest from the source of strain. The Carpenter's stopper is then taken off, and, with the help of the chain-check-stopper, the hawser may be rendered or paid out under perfect control.

In an emergency tow, if the cable gear of the ship to be towed is in working order, it is better that she should provide the cable and hawsers for the towrope, and adjust the towrope to the required length, because the forecastle of a ship is better suited and equipped than a quarterdeck or poop for handling and working the heavy towing gear. It is quite likely, however, that owing to damage or some other trouble the ship to be towed is unable to work her cable gear, and towing ships should always be prepared to provide the necessary hawsers and length of cable, and to adjust the towrope to the required length. In the Second World War it was common practice in cruisers and destroyers to keep a shackle or two of cable ranged aft in preparedness for emergency tows.

Securing the Towrope in Submarines

In a submarine the work involved in connecting the towrope is carried out on her bridge because of her low freeboard. Two towing-slips, which can be released from inside the hull, are fitted just abaft the forward hydroplanes. On each slip is a length of chain cable which is led forward through the bullring and there shackled to a swivel-piece. To each swivel-piece is shackled a 200-ft. towing-pendant of 3½-in. E.S.F.S.W.R., which is led aft on each side to the bridge and clipped or stopped along its length to the casing.

Owing to the limited space available on her bridge the towrope must be hauled over to the submarine by the towing ship, and this is done in the following manner. After connection has been established by gunline a light messenger is passed, to the end of which is bent a 6-in. tail-block through which is rove a 2-in. messenger. The submarine's crew haul across the tail-block and secure

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it; the towing ship's crew haul across the end of the towrope by means of the messenger, and the towrope is then shackled to one or both of the submarine's towing-pendants. As the strain is taken on the towrope the pendants are hauled clear of their clips or stops on the casing.

For a tow of long duration, or one during which heavy weather may be encountered, it is best, if possible, to secure the towrope direct to the end of the submarine's chain cable.

Securing the Towrope in Small Vessels or Craft

Motor gunboats and motor torpedo boats are fitted with towing-plates, one on each bow and one on each quarter, and to each pair of plates is fitted a bridle of 3-in. F.S.W.R. to which the towrope is shackled. These boats offer the minimum drag when in their planing trim, and in calm weather they should therefore be towed at speeds of between 12 and 20 knots. Under these conditions the most suitable towrope for the larger boats is a 30-fathom length of 2¾-in E.S.F.S.W.R. shackled to a 3-fathom length of 8-in manila, and for the shorter boats a 25-fathom length of 2-in. E.S.F.S.W.R. shackled to a 3-fathom length of 6-in. manila should be used. If a longer or heavier rope is used its weight will drag down the bows of the boat and prevent her attaining her planing trim.

If deterioration in the weather necessitates a reduction in the towing speed to below 12 knots the boat will revert to her static trim; she will then become sluggish, will yaw and wallow badly in the troughs of the waves, and in a head sea her bluff bows will punch badly into the waves. Under such conditions the towrope should be considerably lengthened so as to provide a spring, and towing speed should be reduced to 7 knots or under.

The standard towing arrangements fitted to these boats are only suitable for emergency tows of short duration in calm weather; for prearranged long-distance tows the boats should be specially prepared beforehand and fitted with a girdle round the hull to which the towrope should be attached.

For towing a motor gunboat in the Irish Sea in moderate weather and head seas, a girdle of 5-in. manila was fitted round the hull two feet below the gunwale and padded at the sides of the transom with canvas and oakum. It was slung in place on each side by 2-in. manila strops led upward and aft from the girdle to the after and amidship bollards, the deckhouse timbers, and the windlass; in this way the towing stress was distributed between the transom and the fittings from which the girdle was slung.

In small vessels and craft standard fittings such as bollards, capstans and windlasses, and the decks to which they are secured, are not strong enough to withstand the stresses involved in tows of long duration, and arrangements must therefore be made to distribute the towing stresses between as many of these fittings as practicable. The following method was evolved in a small minesweeper with a weak windlass but with strong forecastle bollards, to relieve the windlass of any of the towing stresses; it proved successful over a long-distance ocean tow. The anchors were removed and stowed inboard, the port and starboard cables were led through their respective hawsepipes and made into a bridle by shackling their ends together with a towing shackle, and the bridle was then veered to the length required to provide a suitable spring in

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the towrope. Each leg of the bridle was secured by a Blake-slip on a pendant belayed to the foremost and after forecastle bollards, and cable was veered until the pendants took the towing pull. The fitted Blake-slips were then put on slack as preventers. The stresses of towing were thus divided between the forecastle bollards, and the arrangement allowed the bridle to be veered or hove in as required to freshen the nip or to adjust the length of the towrope.

Towing Aids and Preparations

Propellers

When a ship is being towed the drag of each of her propellers may be as much as, or even greater than, the resistance offered by the underwater surface of her hull. When practicable, the engines should therefore be disconnected from their shafts to allow the propellers to trail.

Radar Reflectors

When it is required to tow a small vessel, or one with very low freeboard such as a motor torpedo boat, or an unrigged battle-practice target, consideration should be given to rigging her with a mast fitted with a radar reflector. This will enable a check to be kept on her in low visibility, and help in her recovery if she breaks adrift or if the towrope has to be slipped in emergency.

Lights

A vessel may have to be towed for a long distance without a crew, and it may be impracticable to provide her with sidelights which will burn throughout the duration of the tow. In these circumstances the towing ship should illuminate the towed ship at night by searchlight when in the vicinity of shipping.

Slipping and Buoying the Towrope

The after towing arrangements of a warship incorporate a slip to enable her to slip the towrope in emergency and so regain her freedom of manœuvre. If the towrope is slipped it will be difficult, and sometimes impossible, for the towed ship to recover it, and when towing is resumed time will be wasted in recovering the towrope or passing a new one. If in sufficiently shallow water the towing ship should therefore buoy the end of the towrope before slipping it, the buoy being rigged with a stave and flag. A good method is to reeve the buoyrope as a double whip through a block shackled to the end of the towrope, the buoyrope being strong enough for weighing the end of the towrope.

Use of Oil in Rough Weather

Heavy seas breaking on board may often be dangerous, especially if the ship is disabled. Even in the roughest weather, however, seas can be prevented from breaking by spreading a small quantity of oil on the surface of the water; a rate of only a few gallons an hour being sufficient. The best oils to use are those of fish, animal or vegetable origin and the next best are ordinary boiler fuel and diesel oil; in cold weather the oil should be heated to decrease its viscosity. The oil can be distributed in many ways, some of which are described below.

(i) Fill a one- or two-gallon tin with oil, punch sufficient holes in its bottom to give the required rate of flow, and place it in a water-closet pan, wash-basin, or bath, so that the oil runs or is flushed outboard through the soil-pipes.

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(ii) Take an old wash-deck hose, cut off the connections, sew up one end and prick a number of holes along its length with a sailmaker's needle. Then fill the hose with oil, close its other end with a strong seizing, and stop the hose to the gunwale at the required position.

(iii) Take a bag, such as a seaman's kit-bag or a coaling-bag, fit it with a two-legged sling, ballast it with about 7 pounds of iron or coal and pack it, not too tightly, with cotton-waste or oakum. Then with a sailmaker's needle prick a number of holes in the bottom and lower half of the sides of the bag, fill it with oil, close its neck with a strong seizing, and trail it in the water on a line.

Both ships should distribute oil, and the positions from which to distribute it will depend upon the direction of the wind and sea. If wind and sea are from abaft the quarter, oil should be distributed from each bow and quarter and from amidships on each side ; if wind and sea are from between the quarter and the bow oil should be distributed on the weather side from the bow, from amidships, and from the quarter ; if wind and sea are from before the bow oil should be distributed from each bow. If wind and sea are before the beam and the towed ship is yawing badly the towing ship should sling the bag described above by a bow-shackle on the towing hawser, tail it with a strong messenger, and allow it to slide well down the hawser so that it will distribute the oil ahead of the towed ship within the limits of her yaw.

If oil is used when taking a vessel in tow the lines and hawsers should, if possible, be kept clear of the oil, otherwise they will become slippery and very difficult to handle.

Preparing a Small Vessel Without a Crew for a Long Tow

The following preparations were made in a motor torpedo boat which was to be towed without a crew for a long distance, and they are described here as being generally applicable to small vessels which have to be towed in similar circumstances.

All hatches and sky-lights were closed and battened down, the holes of ventilating-cowls and the navel-pipes were plugged, the main and auxiliary exhaust pipes were plugged, the self-bailer was shut and all scuttles were secured with their deadlights down. The engines were put out of gear so that the propellers were free to trail, and the stern-glands were " cracked-open " to prevent them overheating. Had time allowed, the propellers would have been removed to avoid having to crack-open the stern-glands.

Provision of Electric Power to a Disabled Vessel

If a damaged and disabled vessel is without steam and electric power it may be possible in calm or moderate weather to supply her by cable with sufficient electric power to enable her to pump out flooded compartments and correct any trim or list, provided that her electrical system is similar to that of the towing ship. In the Second World War a destroyer in danger of sinking was made sufficiently seaworthy by this means to enable her to be towed to port. The cable should be in one continuous length, because it is very difficult at short notice to make a joint in electric cable sufficiently strong and watertight for this purpose. The end of the cable should be bound with tape to make it as watertight as possible, and the cable should be stopped in shallow

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bights, at intervals of three feet, to a 1¼-inch wire-rope jackstay, care being taken to parcel the cable at the stops to avoid chafe. If towing at long stay the jackstay should be slung from the towrope by strong hooks at intervals of 5 to 10 fathoms.

Messengers

If the towing ship has to veer a heavy and cumbersome manila hawser or a length of cable as part of the towrope, a messenger should be shackled to its end to enable it to be hove in by hand or capstan when shortening-in or slipping the tow.

Another method of heaving in a heavy manila hawser which is too big to be taken to a capstan is by nipping it to an endless messenger ; the messenger is rove through a leading-block secured as far forward in the ship as practicable and then brought to the after capstan. The hawser is nipped to the moving messenger at intervals of a few feet, in the manner described on page 123 of Volume I of this manual. This was the method by which the old sailing men-of-war hove in their hempen bower cables.

Towing-pendants in Destroyers

In a seaway it is difficult in a destroyer to secure the end of a heavy towrope directly to the towing-slip on her stern, and a particularly large shackle is required to take both the eye of the hawser and the tongue of the slip.

To overcome this difficulty a short towing-pendant is usually fitted to the slip, thus enabling the connection to be made on deck.

Estimating Depth of the Bight of a Towrope

The depth of the bight of a towrope which consists of a single hawser having its ends suspended at the same level, can be calculated from the following formula :—

$$D = \frac{L\ (\sec.\ \theta - 1)}{2 \tan\ \theta}$$

where :

θ is the angle of slope of the towrope with the horizontal at its points of suspension ;

L is the length of the towrope in feet ; and

D is the depth in feet of the lowest part of the bight.

This formula, however, does not hold good for a composite towrope, and, moreover, it may be difficult to measure the angle θ with sufficient accuracy.

A rough but practical way of estimating the depth of the bight is as follows :— take as accurate a range as possible of the bows of the towed ship from the stern of the towing ship and plot this range on a piece of paper to as large a scale as practicable ; now cut a length of thread equivalent at the same scale to the length of the towrope ; then if the thread is laid along the plotted range at the estimated catenary of the towrope, the depth of its bight can be measured.

Establishing Contact and Passing the Towrope

The method of establishing contact and passing the towrope at sea depends largely upon the weather, the types of the two ships, and the condition and trim of the disabled ship. Provided that the towing ship has good manœuvrability the best method is to approach close to the disabled vessel's bows, establish

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contact by gunline or heaving-line and pass the towrope direct by messenger. large ships may not, however, be sufficiently manœuvrable for this method, and they must therefore establish contact either by boat and grass-line or stream a grass-line so that the other ship can grapple it and pick it up.

Attitude of a Disabled Ship Relative to Wind and Sea

The direction relative to the wind and sea in which a ship will lie when stopped depends upon the position of her superstructure, her freeboard, the shape of the underwater part of her hull, and her trim.

If the ship is trimmed on an even keel the direction in which she will lie depends upon her freeboard and the position of her superstructure. Ships with a high forecastle and a superstructure disposed well forward, such as tugs, will lie with the wind somewhat abaft the beam. Ships with their superstructure disposed evenly amidships, such as battleships, liners and some freighters, will lie broadside on to the wind. Ships with their superstructure right aft, such as tankers, some bulk-freighters and some coastal vessels, may lie with the wind somewhat before the beam.

The more a ship is trimmed by the stern the farther will she lie off the wind, conversely the more she is trimmed by the head the nearer will she lie to the wind. The lighter a ship is laden the greater will be the effects of an uneven trim and the position of her superstructure. A deeply laden three-island freighter will probably lie broadside on to the wind, but the same ship in ballast, trimmed slightly by the stern to give adequate propeller immersion, will probably lie with the wind well abaft the beam.

Damaged plating projecting below the keel will have an effect similar to that of uneven trim, particularly if it is well aft or forward, because of the drag it offers to the drift of the ship to leeward.

Drift of a Disabled Ship

The speed at which a ship drifts to leeward depends upon the strength of the wind, her draught, her freeboard, and the area of her superstructure; and the more lightly laden she is the faster she will drift. A freighter, averagely laden, may drift in a gale at a speed of as much as 2 knots.

A ship lying with bow or quarter to the wind will tend to sail and so gather a little sternway or headway as she drifts, and this combined with the effect of the waves will make her yaw. This should be borne in mind when establishing contact and passing the towrope at close quarters.

Establishing Contact by Boat

It is best to lower a boat in the lee of the disabled ship and thus take advantage of the area of relatively calm water and of her drifting towards the boat. Fig. 29 shows the shape and extent of the area of the lee afforded by a ship: (i) when lying broadside on to the wind and drifting directly before it, and (ii) when lying with the wind on the bow and drifting to leeward and astern. In both cases the boat should be lowered within the apex of the triangular area, and in the first case she should steer for the centre of the ship, but in the second for a point farther aft, otherwise she may fetch up under the disabled ship's bows.

The value of using oil to calm the sea for boatwork is questionable. If advantage is taken of the lee afforded by the disabled ship, then the towing

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ship will have to spread a patch of oil beforehand in the path of the other's drift, any lines towed by the boat will become oily and therefore difficult to handle, and if the boat ships any oily water the work of her crew will be considerably hampered. Unless the situation is urgent it is therefore better to wait until the weather moderates, or to use some other means of establishing contact.

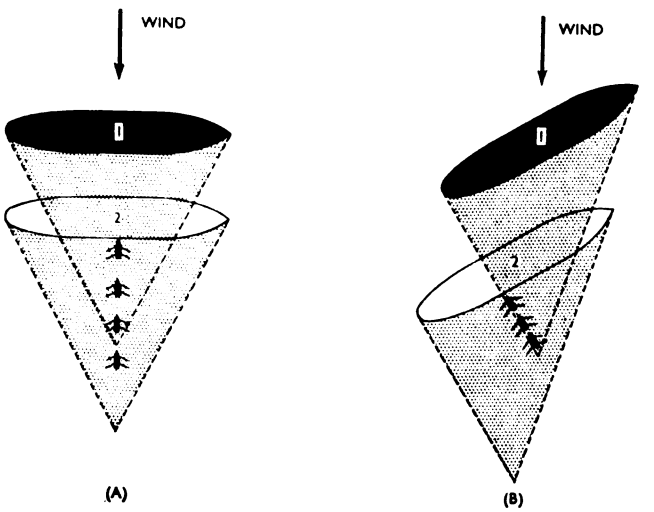

Fig. 29. Lee for a boat afforded by a drifting ship

Establishing Contact by Streaming a Grass-line

There are several different ways of establishing contact by streaming a grass-line with its end bent to a small buoy, life-buoy, or a cask. One is for the disabled ship to pay out the line from her weather side as she drifts to leeward; the line will then be streamed to windward of her where it can be grappled and picked up by the towing ship. Alternatively, the towing ship can stream the grass-line while under way and tow it so that it will lie to leeward of the disabled ship and in the path of her drift; then as the disabled ship drifts over the line she can grapple it and pick it up.

Another method is for the towing ship to bend the end of her grass-line to a small target or a float rigged with a sail. She then stops to windward of the disabled ship, casts the target overboard and allows it to sail down wind to the disabled ship, carrying the end of the grass-line with it.

Establishing Contact by Gunline

The manœuvring of the towing ship will depend largely upon the angle with the wind at which the disabled ship is lying, and the angle with the wind at which the towing ship will lie when stopped. It should also be borne in mind that when moving astern all ships tend to come stern up to the wind, this tendency being more marked in ships with their superstructures forward or amidships than in those with their superstructures aft.

It is recommended that the towing ship should pass the lines and messengers from her forecastle and the towrope from aft; her captain will then have a close and unobstructed view of the proceedings and therefore be better able

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to manœuvre his ship as required during the initial and most critical stage of the operation when the ships are very close together. In preparation for this method about 15 fathoms of the messenger should be flaked down on the forecastle, the remainder being led aft outboard of all, stopped at intervals to the gunwale, and then led inboard through the towing fairlead.

Towing

Taking-up the Tow

When the end of the towrope has been secured, the towing ship should move slowly ahead while veering the towrope to the required scope, and then stop while the towrope is finally secured in both ships ; in shallow water care must be taken at this stage to keep the bight of the towrope off the bottom. The towing ship should then take up the tow by giving a series of kicks ahead on her engines, so as to subject the towrope as gradually as possible to the stresses of getting the towed ship under way. As the towed ship gathers way the intervals between these kicks ahead can be diminished, and on reaching a speed of about two knots the engines can be kept moving continuously and speed be gradually increased until the required towing speed is attained

Great care and patience should be exercised when taking up a tow because the stresses involved in overcoming the inertia of the towed ship are much greater than those of towing her at a constant speed. The best way to judge the degree of stress in a towrope is to watch its catenary ; the shallower the catenary the greater, of course is the stress in the towrope, and it increases rapidly to infinity as the rope straightens out. The best practical rule for avoiding undue stresses in the towrope, both when taking up the tow and when towing, is never to allow its bight to break surface.

Towing

Provided that the tow is riding comfortably astern and not yawing there are no particular problems involved in towing. The bight of the towrope should be kept well immersed, and in a swell its length should be adjusted so that both ships rise together on the crests of the waves and fall together in the troughs. Care should be taken to keep the bight of the towrope off the bottom, because if it fouls the bottom both ships will be brought up with perhaps serious results, particularly if the towing course lies across the wind or current. The nip of the towrope should be freshened in both ships at regular intervals, fairleads and hawsepipes should be kept well greased, and hawsers should be kept well parcelled where they pass through fairleads and hawsepipes.

If the bight of the towrope shows a tendency to break surface, either the towrope should be lengthened or the speed of towing should be reduced. If the weather deteriorates the bight of the towrope should be immersed deeper, provided that there is a sufficient depth of water, and this is best done by veering cable. If there is insufficient water to increase the depth of the bight then speed should be reduced.

Provided there is sufficient sea-room to leeward, it is better to run before a strong gale than to heave to heading into it, because the force required to keep both ships heading into wind and sea is usually excessive, and imparts very heavy stresses on the towrope. In a particularly strong gale consideration should be given to slipping the tow and allowing both ships to drift independently of each other before the gale ; the towing ship will then have complete freedom of manœuvre, and the towed ship should ride quite comfortably with the towrope acting as a sea anchor.

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Any large alteration of course should be made in steps of a few degrees at a time so that a steady strain is maintained in the towrope, otherwise its bight will sag and may foul the bottom.

The average rate of progress on a long-distance tow may be as little as four knots, and at this low speed the effects of wind and current on the navigation of the towing ship may be considerable. Wind charts, current atlases and weather forecasts should be carefully studied, and the track of the ships should be plotted to take advantage of any favourable winds and currents and to avoid any adverse ones. In towing the shortest route is not always the quickest.

Yawing

Most vessels when in tow have a tendency to yaw to one or both sides of the course, but if the yaw is not excessive and the towed ship is able to steer, no difficulty should be experienced. If the towed ship is unable to steer and the yaw is excessive the towrope will be subjected to considerable stresses, particularly at the limit of each yaw, and it may also be severely chafed or badly nipped.

The following factors, singly or in combination, may make a ship yaw or contribute towards her tendency to yaw :—

(i) the direction and force of wind and sea relative to her course ;
(ii) her freeboard, draught, and the disposition of her superstructure ;
(iii) her trim ;
(iv) any list she may have on her ;
(v) any underwater projections caused by damage to her hull.

The more deeply laden is a ship the less tendency will she have to yaw, and of the yawing factors trim has the greatest effect.

EFFECT OF WIND AND SEA

With an undamaged ship in normal trim little can be done to correct yawing caused by wind and sea except by altering course or altering the speed of towing. A ship with a high forecastle and superstructure forward, such as a destroyer, will tend to bore up to windward, and a ship with her superstructure aft, such as a tanker, will tend to pay off to leeward. In a cross-wind the destroyer will probably first fall off to leeward and then bore up into the wind, and so yaw from one side of the course to the other, whereas the tanker will probably pay off to leeward and then ride there at a steady angle of sheer. In a following wind and sea the tanker, particularly one with a counter-stern, will tend to yaw more than a destroyer ; but in a headwind there should be little tendency for either type of ship to yaw.

EFFECTS OF TRIM, LIST AND UNDERWATER PROJECTIONS

The more a ship is trimmed by the stern the steadier will she be when in tow, and conversely, the more she is trimmed by the head the greater will be her tendency to yaw. In fact a ship trimmed well down by the head will be unmanageable if towed bows first, and she should therefore be towed stern first.

A ship with a list will tend to sheer off towards her high side, and this tendency will be increased by a cross-wind blowing on that side ; but a cross-wind blowing on her low side will tend to steady her.

Underwater projections caused by damage to the hull structure will have an effect similar to that of trim or list ; if the projections are before the ship's

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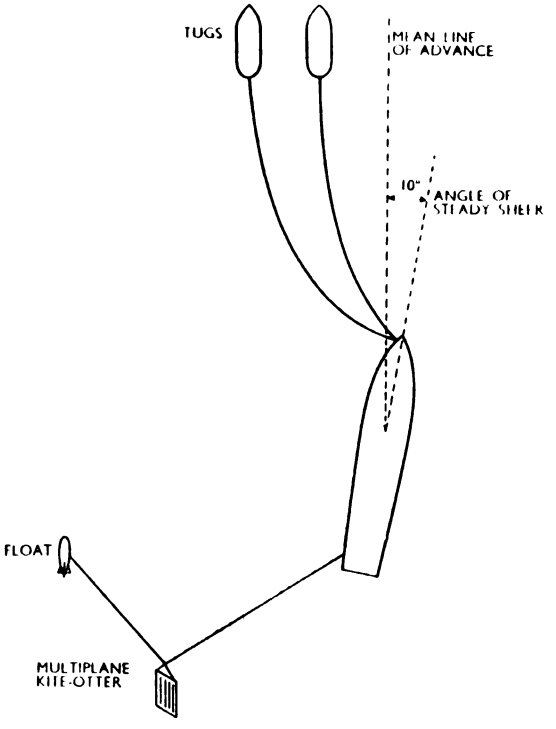
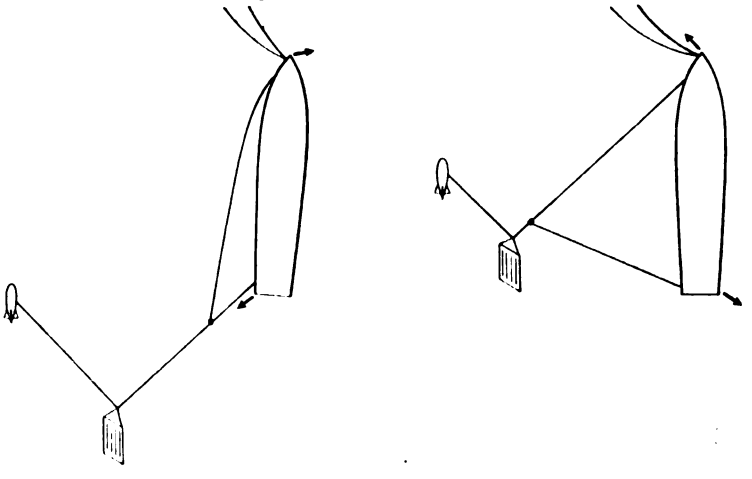


(i) Correcting a yaw by streaming a multiplane kite-otter



(ii) Suggested method of adjusting the angle of sheer by shifting the point of tow from the quarter to the bow

Fig. 30.

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pivoting point the effect will be the same as if she were trimmed by the head, and *vice versa*, and if they are to one side of her centre line she will tend to sheer towards that side.

CORRECTION OF YAW

Yawing may be corrected or reduced in a number of ways, and the choice of method must depend upon its cause and the circumstances of the tow.

The chief cause of yawing is usually that the ship is not trimmed sufficiently by the stern. Trim is best corrected by transferring liquids or ballast from one part of the ship to another, because then her reserve of buoyancy is maintained. If trim is corrected by flooding or by adding ballast, it should be done with discretion, otherwise the ship's stability, reserve of buoyancy, or seaworthiness may be dangerously affected. A great advantage of altering the trim of a ship to correct a yaw is that it does not increase the drag of the ship on the towrope.

If altering the trim of the ship is impracticable, or if her yawing is not due to incorrect trim, one or other of the methods described below should be tried. These have all proved successful in practice, but it should be borne in mind that most of them increase the drag of the towed ship, and may subject the towrope to undue stresses, or to a bad nip or undue chafe. Increasing the drag may well reduce the speed of towing to below what is economical or efficient.

(i) *Altering the speed.*—Yawing may be increased or reduced by altering the speed of towing. Yawing caused by list is usually decreased by increasing the speed of towing, and yawing caused by trim is usually decreased by reducing the speed of towing.

(ii) *Setting the rudder.*—Though a ship's steering gear may be damaged her rudder may still be workable by hand, either by gearing or by reeving tackles on the tiller. By setting her rudder at an angle the towed ship may be steadied at a constant angle of sheer to one side or the other of the towing ship's track, but it may then be necessary to alter the lead of the towrope to ensure that it is not subjected to a bad nip or undue chafe.

If the rudder-angle or the angle of sheer is large this method may be impracticable because of the increased drag of the towed ship.

(iii) *Steering a rudderless but otherwise undamaged ship.* In the Second World War a ship which had lost her rudder, but which was otherwise undamaged, used the rescue ship as a rudder by taking her in tow. By keeping a slight stress on the towrope and by sheering slightly as required to one side or the other of the course, the rescue ship was able to steer the rudderless ship fairly steadily on the required course in a high wind and sea. By this means a much greater rate of progress was achieved than if the rescue ship had towed the other in the orthodox manner.

(iv) *Streaming a multiplane kite-otter.*—In the Second World War a rudderless and disabled ship in tow of two tugs was yawing uncontrollably through an angle of 120 degrees. The yaw was corrected and the ship steadied at an angle of 10 degrees to the towing course by streaming a multiplane kite-otter from her quarter as shown in Fig. 30 (i). (For a description of the multiplane kite-otter see page 441 of Volume II of this manual.)

This method might be modified to adjust the angle of sheer to within finer limits, as shown in Fig. 30 (ii).

(v) *Shifting the point of tow.*—A ship which is yawing to one side of the course may be steadied at a constant angle of sheer by shifting the point

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of tow farther aft on the inner bow. This is only practicable, however, if the resultant angle of sheer is not too great, and if the towrope is not subjected to a bad nip or undue chafe.

(vi) *Setting sails.*—A yaw can be steadied or reduced to within practical limits by rigging and setting a sail as far forward or as far aft in the ship as practicable. In small ships, such as destroyers, a cutter's or whaler's mainsail is quite effective. In larger ships one of the ship's awnings could be used, bent to the foremast forestay or the mainmast backstay.

(vii) *Towing a drogue.*—A drogue towed astern by a small ship with fine lines, such as a destroyer, has proved very effective in steadying her when in tow. Drogues which have been successfully used for this purpose include a 6-inch manila hawser, doubled, and towed in a bight ; one or two shackles of the ship's cable streamed on a messenger ; and a provision net, filled with shot mats and towed on a two-legged bridle.

(viii) *Propellers.*—A propeller, because of the drag it affords, has a steadying effect on a single-screw ship. In a multiple-screw ship a yaw or a sheer may be reduced by allowing one of the propellers to trail, thereby reducing the drag on that side of the ship.

Towing Alongside

Towing another ship alongside is not recommended except in the calm waters of a harbour, because if the ships pitch or roll at all they are certain to damage each other. The best method of securing two ships alongside one another is by a head-spring and a back-spring led from bow to quarter and quarter to bow, and by a forward breastrope and an after breastrope led from well forward and well aft in each ship (see Fig. 31). Both ships should be well fendered amidships. Provided that the inner propellers of each ship are well clear of each other the breastropes should be adjusted so that the ships lie parallel, but if there is a danger of the propellers fouling each other the bows of the ships must be bowsed in by the forward breastrope so that their sterns lie well apart.

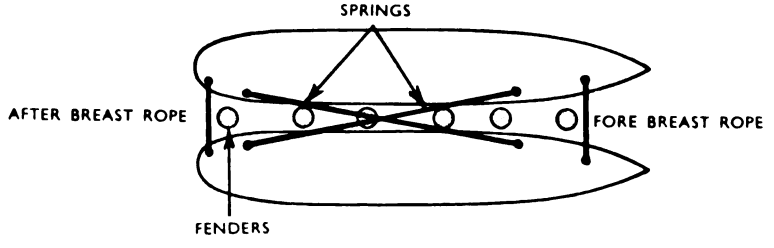

Fig. 31. Arrangement of hawsers and fenders for towing another ship alongside

If the towing ship is not particularly powerful or manœuvrable she should lead the springs and breastropes so that her stern projects well abaft the other ship's stern. She will then find it much easier to manœuvre and control the other ship than if she were secured abreast her.

Towing off a Stranded Ship

Much depends on the type of the towing ship, the depth of water, and other circumstances when deciding how best to tow a stranded ship off the shore.

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For an emergency tow of short duration and where the water shoals rapidly close inshore on a rocky bottom, it may be best to tow from forward if the ship is powerful, easily manœuvred and has good astern-power, like a destroyer. The advantages of towing from forward are that there is less likelihood of the ship's rudder and propellers fouling either the bottom or the towrope, and the captain has an unobstructed view of the proceedings and can watch the catenary of the towrope. It may also be to advantage to tow from forward when the wind is blowing directly on to the shore because it is easier to keep a ship stern to wind than head to wind, but if the wind blows the funnel smoke over the bridge this method may be impracticable. Towing from forward in shallow water with a muddy or sandy bottom is not recommended, because the wash of the astern-going propellers will probably disturb the bottom, and the ship's condensers will then probably be choked.

In other circumstances it will probably be best to tow from aft because a ship can exert greater power over a longer period when her engines are going ahead than when they are going astern.

Whenever possible the towrope should be secured in the towing ship somewhere near her pivoting point, because then her stern will not be girded by the towrope and she will be able to maintain her towing course even if a wind is blowing or a current is running parallel with the shore. She may, of course, take a list towards the side on which the towrope is secured.

If it is impracticable to secure the towrope anywhere but right aft, and if the towing ship is being set to leeward of her course by wind or current, a spring shackled on to the bight of the towrope and led inboard through a bow fairlead may enable the ship to hold up to her towing course.

Before attempting to tow a stranded ship off the shore the seaman should study the chapter on " Salvage Operations " in this volume, because so much depends on the condition of the stranded ship and her situation.

Towing an Anchored and Disabled Ship off a Lee Shore

An emergency tow of this sort usually has to be carried out in a strong gale to prevent the anchored ship from dragging her anchor and stranding on a lee shore. Taking in tow under these conditions will probably be complicated because of the limited manœuvring room available to the towing ship, the yawing of the anchored ship, and the danger of fouling her cable.

The best method of passing the towrope under these circumstances is first to watch carefully the extent of the yaw of the anchored ship, and then manœuvre the towing ship so that she lies stern to wind in a position just clear and abreast of the bows of the anchored ship when she reaches the limit of her yaw. As soon as the towrope is passed, the towing ship can either steam astern and tow from forward, or if this is impracticable because of the seas she must turn and tow from aft. If the anchored ship can be towed towards her anchor she may be able to weigh it as she is towed clear, otherwise she should buoy and slip her cable.

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CHAPTER VIII

Moorings

PERMANENT moorings may be laid for the following purposes :—

(i) making the most of the usually limited space of a harbour anchorage ;
(ii) berthing ships as near as possible to the landing places so as to facilitate embarking and disembarking stores, cargo, crew or passengers ;
(iii) providing secure moorings for ships in crowded waters, especially for those laid up and others unable to move under their own power ;
(iv) facilitating port administration by enabling ships to enter and leave with a minimum use of tugs ;
(v) ensuring that ships are berthed exactly, and in the most suitable positions for each other's safety and for the preservation of lanes for harbour traffic ;
(vi) reducing the possibility of ships dragging in heavy weather. (A ship is usually more secure at a permanent swinging mooring than at anchor.)

The two main types of permanent mooring are the swinging mooring where a ship secures head to a buoy and is free to swing to the wind and tidal stream, and the head-and-stern mooring where a ship secures head and stern between two buoys. Where space permits swinging moorings are always laid because they are the more secure, and ships can make fast to them and slip from them with the minimum of help. Where space is limited, however, ships must be secured to head-and-stern moorings, which have the following disadvantages :—

(i) a ship usually requires tugs when securing to them and slipping from them, particularly when the wind is athwart the line of moor ;
(ii) when a ship is secured to them in a strong beam wind they are subjected to a very great load and so they have to be particularly strong and secure ;
(iii) a mooring intended for a long ship is not suitable for a short ship.

Parts of a Mooring

The three main parts of a mooring comprise the ground tackle, the buoy-pendant and the buoy, as shown in Fig. 32 which illustrates a simple two-arm mooring.

Ground Tackle

This consists of one or more mooring anchors, with an arm of mooring chain shackled to each and led to a central mooring ring, to which is shackled the buoy-pendant.

Mooring anchors (Fig. 33).—These are usually stocked, single-fluke anchors, and they are usually heavier than the bower anchors of the ships for which the mooring is designed. They are carefully placed and embedded to ensure that the mooring and its buoy are in the correct position. Because they are seldom dropped and embedded by dragging like a ship's anchor they have only one fluke, and a stock is incorporated to prevent the anchor from rolling out of its bed. A small explosive charge may be used to dig a hole for the fluke of a mooring anchor when the harbour bottom is unusually hard. Mushroom

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anchors are sometimes used instead of fluked anchors when the bottom is of a particularly soft or muddy nature.

A ship's stockless anchor is not suitable as a mooring anchor unless its flukes are wedged at the full angle of their travel and it is provided with a stock of about the same length as the shank and fitted just below the ring. The anchor must then be laid flukes downward and embedded by dragging.

Ferro-concrete or cast-iron clumps are sometimes used in moorings to provide extra weight along the arms of ground tackle between the anchor and the mooring ring, and for minor moorings they may be used instead of anchors. These clumps give good holding power in a soft muddy bottom, but hard ground should be loosened for them by small explosive charges or by grab-dredging. They are not used in shallow water, and they lose 30 per cent of their weight owing to buoyancy when submerged.

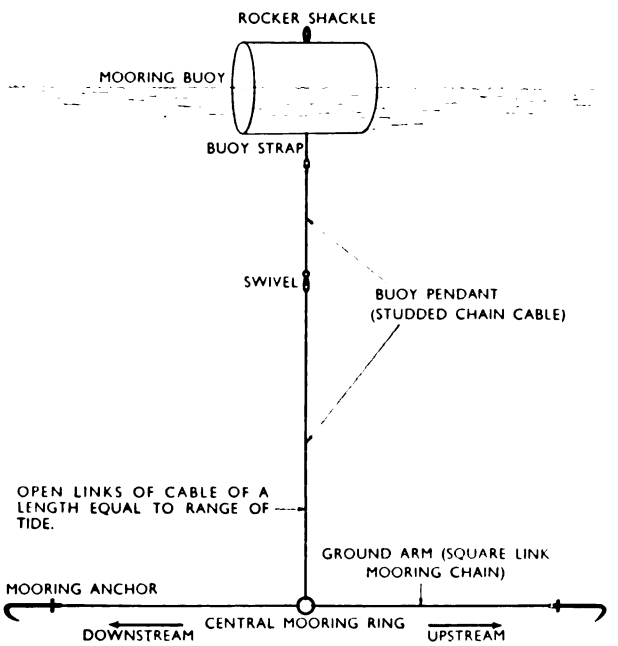

Fig. 32. Parts of a mooring—two-arm type

Arms of ground tackle.—These are made up of lengths of special "square-link" mooring chain, composed of long square-section links, the lengths being joined by a special forelock-shackle, as illustrated in Fig. 33. Forelock shackles are used because they are easier for divers to handle under water than pin-and-pellet shackles. Clenched anchor shackles are used, however, where movement is likely to occur, where the inner ends of the arms are shackled to the central mooring ring for example. Clenched shackles have to be clenched before the moorings are laid, and they are therefore used sparingly.

Buoy-pendants

These are more subject to tension and torsion than the arms of the ground tackle, and they are therefore made up of lengths of ordinary studded-chain cable which are joined together by clenched anchor-shackles. A short length

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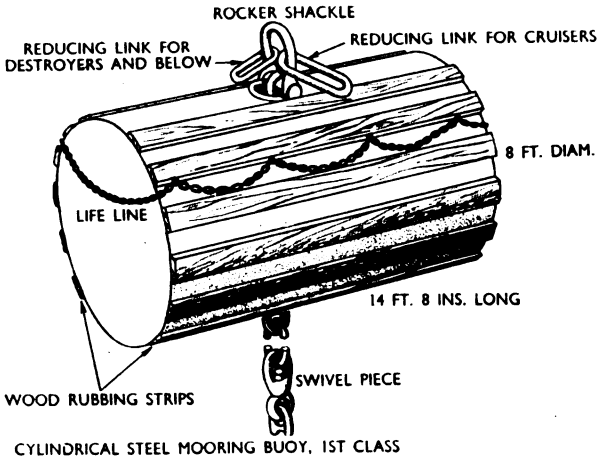
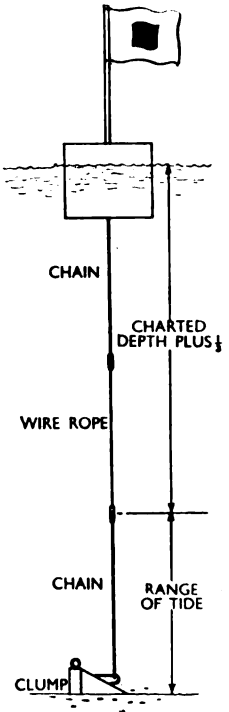
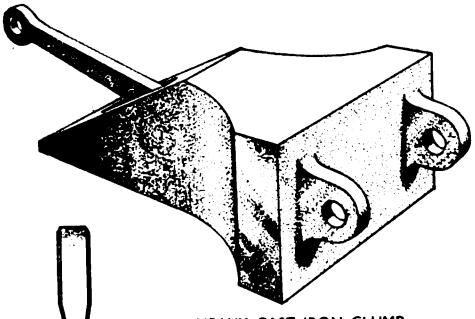


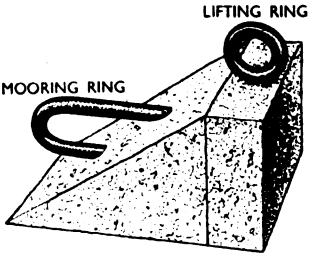
CYLINDRICAL STEEL MOORING BUOY, 1ST CLASS



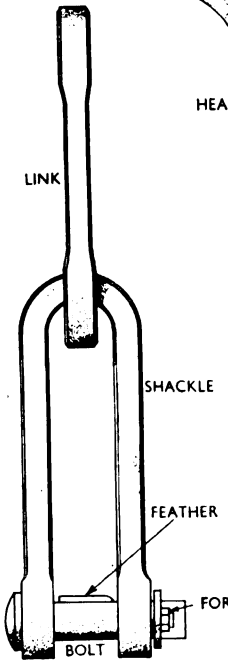
MARK BUOY MOORING



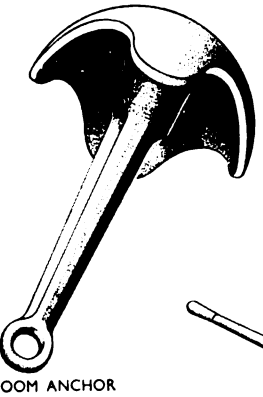
HEAVY CAST IRON CLUMP



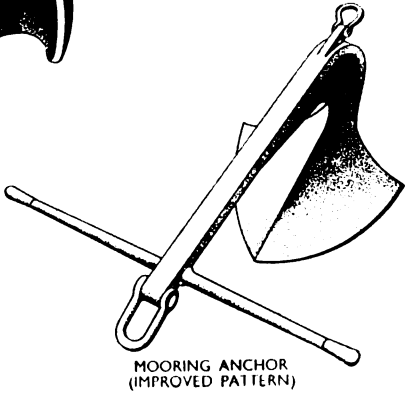
SMALL FERRO-CONCRETE CLUMP



SQUARE-LINK AND FORELOCK MOORING SHACKLE



MUSHROOM ANCHOR



MOORING ANCHOR (IMPROVED PATTERN)

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Fig. 33. Types of buoys, and ground tackle for moorings

of studded-chain cable, known as the " buoy-strap," which is long enough to go through the trunk of the buoy, is shackled to the upper end of the buoy-pendant ; the strap is subjected to more wear and tear than the pendant and so is renewed more often. A buoy-pendant is always fitted with a swivel, even if it is part of a head-and-stern mooring, because then its buoy can always be used as a swinging mooring if necessary. The swivel is inserted at one-third of the length of the pendant from its upper end.

The lower end of the buoy-pendant of the heavier moorings is made up of end links of cable, usually of a size larger than the rest of the pendant to allow for the excessive wear caused by the rise and fall of the tide. The length of the part of the pendant thus reinforced is equal to the maximum range of the tides.

The length of a buoy-pendant or a bridle is decided by the depth of water at H.W. springs, and also by the required freeboard of the buoy when it is supporting the pendant ; to this is added a length of spare slack, usually one fathom, or as decided by the mooring officer.

Buoys.

Mooring buoys.—All modern Admiralty mooring buoys are built on the trunk principle, are cylindrical in shape, and divided into watertight compartments by longitudinal and transverse bulkheads. The buoy-strap is led up through a central trunk in the buoy, and the pin of the rocker-shackle is passed through the end link of the strap. The ship's cable is shackled directly to the rocker-shackle, or to a reducing-link on the shackle if the mooring is designed for a heavier type of ship.

The size of a buoy depends on the size and length of the pendant which it supports, and also on the reserve of buoyancy which the buoy is required to have ; for the higher classes a reserve of buoyancy of 35 per cent is usually allowed, but this may be reduced to a minimum of 25 per cent if necessary ; for the lower classes the corresponding reserves of buoyancy are 20 per cent and 15 per cent. There are six classes of mooring buoys which correspond generally with the six classes of moorings, but in deep water a buoy may be of a higher classification than its mooring because it has to support a long buoy-pendant. The table on page 158 shows the various classes of mooring buoy and the size and maximum length of pendant with which each is designed to be used in normal circumstances. Moorings, except those of the highest class, can be laid in greater depths than those indicated in the table if a buoy of sufficient size is provided to support the pendant ; at Nauru and Ocean Islands in the Pacific moorings have been laid in 200 fathoms of water.

Modern mooring buoys are usually of the horizontal cylindrical type illustrated in Fig. 33, but some of the older " peg-top " type of mooring buoy may still (1954) be in use. This type was discontinued because they were liable to tilt dangerously and so fling any " buoy-jumpers " into the water.

Mark-buoys.—Floating temporary marks are required for many purposes, for example :—

(i) to mark ranges for target practice ;
(ii) to indicate the limits of a minefield when laying or clearing mines
(iii) to mark the course for a regatta ;
(iv) to mark shoals, rocks and channels when surveying.

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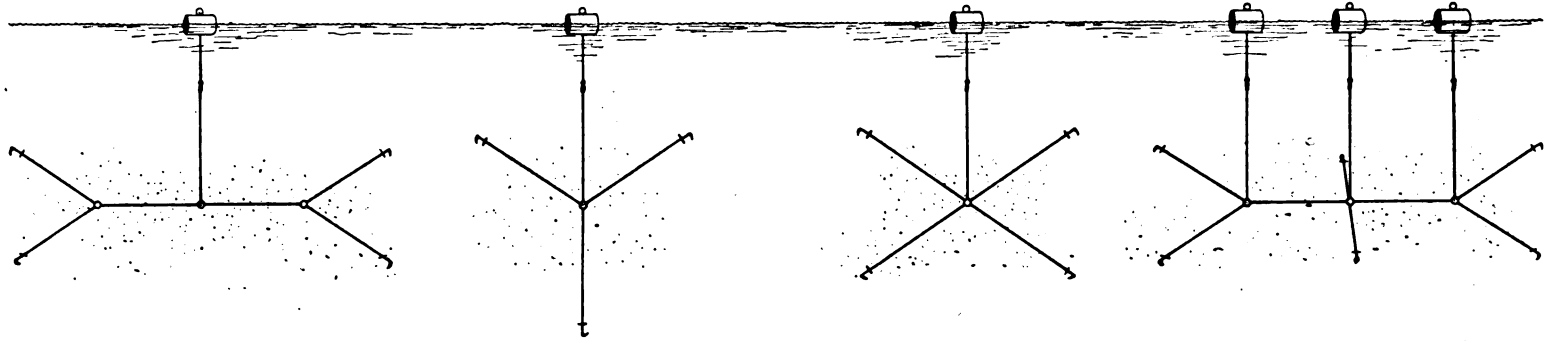
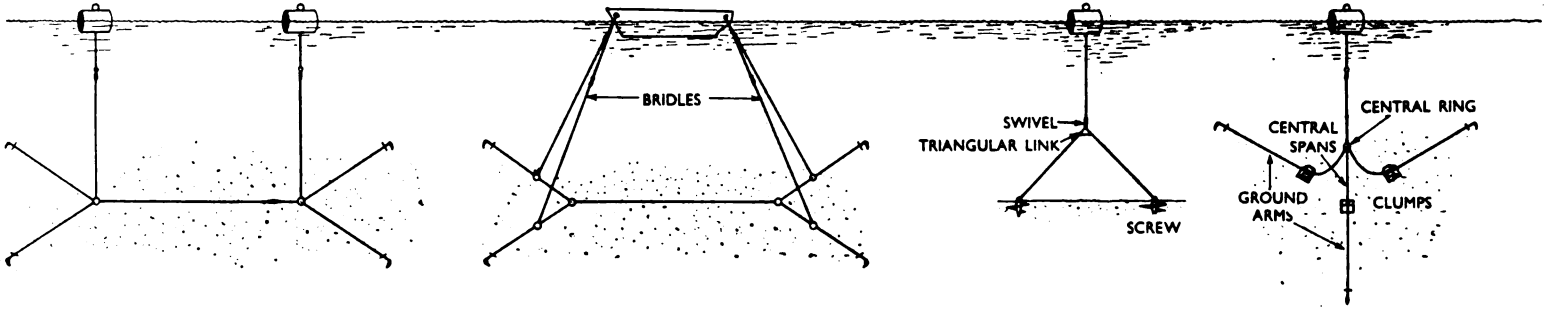


(i) Span mooring

(ii) Three-arm mooring

(iii) Four-arm mooring

(iv) Trot mooring



(v) Head and stern mooring

(vi) Bridle type four-arm mooring

(vii) Screw-type mooring

(viii) Resilient type mooring

Fig. 34. Types of moorings for ships

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When possible, a mark-buoy should be moored to a clump or to a close-stowing anchor, and not to an Admiralty pattern anchor, because when sweeping round with the wind or tide its pendant is almost certain to foul the upper fluke of an Admiralty pattern anchor and possibly trip it so that both anchor and buoy will drift away.

Small casks, pieces of wood, or spars may be used as mark-buoys, and they answer fairly well where there is little wind or tidal stream, but if the mark or flag erected upon it is to be seen from a distance when a fresh breeze is blowing or a strong current running, something more stable is required. In the Royal Navy two types of mark-buoy are provided, namely, the Dan buoy, which is described in Volume II of this manual, and the Standard Surveying Beacon (illustrated in Fig. 37 on page 164) which can carry a far taller and more conspicuous mark than the Dan buoy.

A suitable mooring for this latter buoy is shown in Fig. 33. The manila or wire pendant should be adjusted so that the total length of the buoy-pendant will be about one third more than the greatest depth of water at the position in which it is proposed to lay the buoy, thus allowing for the effects of any tide, tidal stream or current. The buoy is designed to support, with 14 per cent reserve buoyancy, 4¼ cwt., or 15 fathoms of ⅞-in. chain, and the pendant should not exceed this weight.

Types of Moorings

Single-clump mooring.—The simplest form of mooring consists of a buoy, buoy-pendant and clump anchor, as illustrated in Fig. 33. It is generally used for mark-buoys and for small craft such as harbour launches and lighters. The consequences of slight dragging are not serious because the weight of the clump will help to re-bed it, and it is easily returned to its position.

Two-arm mooring.—The lighter swinging moorings in restricted waterways may be of the two-arm type illustrated in Fig. 32, one anchor being laid on the end of an arm of mooring chain upstream, and another on a similar arm downstream. The disadvantage of this mooring is its lack of resistance to dragging when the wind is across the stream, and to return it to its original position when once it has dragged is a major operation.

Span mooring.—The heavier types of swinging moorings may be of the span type, each of the two main arms being provided with two anchors, as illustrated in Fig. 34 (i). The disadvantage of this mooring is also its tendency to drag when the wind is across the stream, and the consequences of a larger ship dragging are, of course, more serious.

Three-arm mooring. (Fig. 34 (ii)).—This swinging mooring is the most satisfactory from the point of view of security, and it is used generally for the heavier types of swinging moorings. Its resistance to dragging is nearly constant with the wind from any point of the compass, but it occupies a wider area than the span and the two-arm moorings.

Four-arm mooring (Fig. 34 (iii)).—This swinging mooring is used for the heaviest types of ships. It has all the advantages of the three-arm mooring, and its four arms provide greater security.

Trot mooring (Fig. 34 (iv)).—This type of mooring is laid for securing numbers of destroyers or smaller vessels in line, head to stern. It economises in space and material.

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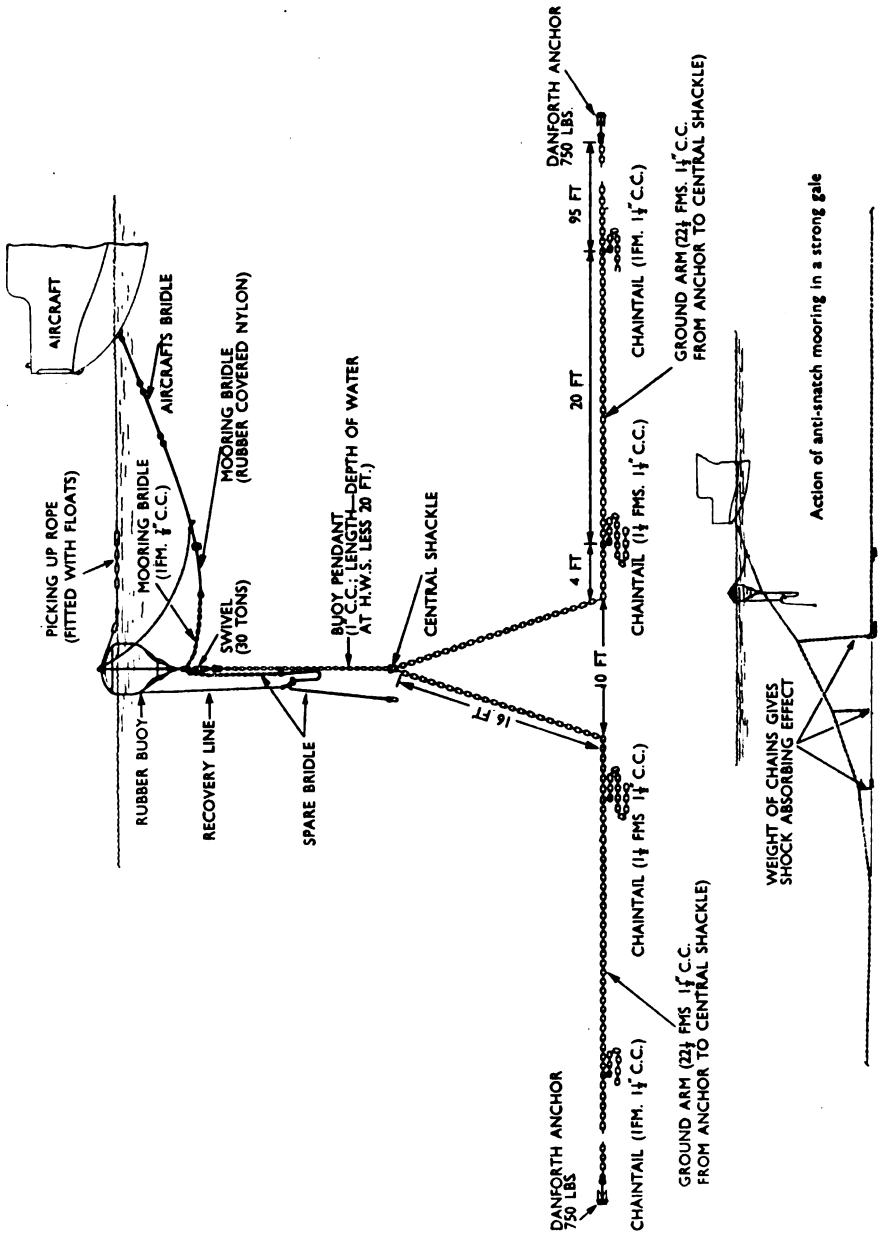
AIRCRAFT
PICKING UP ROPE (FITTED WITH FLOATS)
MOORING BRIDLE (1FM. 1" C.C.)
AIRCRAFTS BRIDLE
MOORING BRIDLE (RUBBER COVERED NYLON)
SWIVEL (30 TONS)
BUOY PENDANT (1" C.C.; LENGTH—DEPTH OF WATER AT H.W.S. LESS 20 FT.)
CENTRAL SHACKLE
RUBBER BUOY
RECOVERY LINE
SPARE BRIDLE
16 FT
4 FT
10 FT
20 FT
95 FT
DANFORTH ANCHOR 750 LBS.
CHAINTAIL (1FM. 1½" C.C.)
CHAINTAIL (1½ FMS. 1½" C.C.)
GROUND ARM (22½ FMS. 1½" C.C. FROM ANCHOR TO CENTRAL SHACKLE)
Action of anti-snatch mooring in a strong gale
WEIGHT OF CHAINS GIVES SHOCK ABSORBING EFFECT

Fig. 35. Anti-snatch type of mooring for small craft and flying-boats

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Head-and-stern mooring (Fig. 34 (v)).—This is the type of mooring generally used for mooring a ship head and stern. Each of its component parts is at least of the same size or weight as those of a corresponding swinging mooring.

Bridle-type, four-arm mooring (Fig. 34 (vi)).—This is the most secure type of head-and-stern mooring, but it is very cumbersome and is therefore only used for mooring ships which are laid-up permanently, such as hulks and training ships. The four bridles are led inboard through hawsepipes on each bow and quarter of the ship.

Screw-type mooring (Fig. 34 (vii)).—This swinging mooring is used largely in commercial ports and rivers. It is very economical in material but is only suitable for harbours with fairly hard bottoms in which it holds well. Its great disadvantage is that if the screws draw they entirely fail to hold as they have little deadweight and no power to regain hold. For this reason screw-type moorings are little used in Naval ports.

Resilient-type mooring (Fig. 34 (viii)).—Until the Second World War the arms of the ground tackle were laid out as tautly as possible to ensure that their central ring was in its correct position, and to prevent any tendency of the mooring anchors to drag. Research and experiment have since proved, however, that the anchors are less liable to drag if some resiliency is incorporated in the mooring. This is done by including a certain amount of slack chain (known as the " central span ") between the inner ends of the ground arms and the central ring, and by incorporating clumps at the inner end of each arm, as shown in Fig. 34. The central spans and the weight of the clumps absorb the sudden stresses imposed on the mooring by squalls or the pitching and surging of the ship in heavy weather.

Anti-snatch mooring (Fig. 35).—During the Second World War the Air Ministry developed a light type of resilient swinging mooring for flying-boats which proved eminently satisfactory for these craft in strong winds and heavy seas. The slack chain at the centre of the mooring, together with the " drag chains," not only damp down the stresses imparted to the mooring anchors but also reduce the tendency of the craft to " snatch " at the mooring in heavy seas, thus enabling them to ride out a strong gale without damage. This mooring has also proved very suitable for coastal craft, small vessels and targets. A description of how to lay this type of mooring from a R.A.F. general-service 60-ft. pinnace is given later on in this chapter.

Classification of Moorings

Because of the great differences in length and displacement of ships several classes of moorings must be provided. Moorings are classified according to the size of the cable of the ships which may safely use them ; generally speaking, first-class moorings are suitable for battleships and aircraft carriers, second-class for cruisers and large auxiliaries, third-class for light cruisers and small auxiliaries, fourth-class for destroyers and frigates, and fifth- and sixth-classes for other smaller ships and craft.

A ship should not secure to a lighter class of mooring than that designed for her, but cruisers and smaller ships may use heavier swinging moorings than those specified for them, and also heavier head-and-stern moorings if the length between the head and stern buoys is not too great. For this purpose one or two special " reducing-links " are fitted to each rocker-shackle of the heavier moorings to enable the buoy-shackle of a smaller ship to be joined to the

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PENDANTS FOR MOORING-BUOYS

BUOY (CYLINDRICAL)			MOORING CLASS	PENDANTS FOR 35% RESERVE BUOYANCY	PENDANTS FOR 25% RESERVE BUOYANCY
CLASS	LENGTH	DIAMETER			
Monster 1st 4 compartments	16 ft. 0 in.	8 ft. 0 in.	1st	9 fms. 4½ in. c.c. + 4½ fms. 5 in. end links	12 fms. 4½ in. c.c. + 6 fms. 5 in. end links
			1st	13 fms. 4 in. c.c. + 4 fms. 4½ in. end links	20 fms. 4 in. c.c. + 4 fms. 4½ in. end links
1st 4 compartments	14 ft. 8 in.	8 ft. 0 in.	1st	10 fms. 4 in. c.c. + 4 fms. 4½ in end links	15½ fms. 4 in. c.c. + 4 fms. 4½ in. end links
			1st	12 fms. 4 in. c.c. + 4 fms. 4 in. end links	17 fms. 4 in. c.c. + 4 fms. 4 in. end links
			2nd	16 fms. 3½ in. c.c. + 6 fms. 3½ in. end links	23 fms. 3½ in. c.c. + 6 fms. 3½ in. end links
2nd 4 compartments	13 ft. 2 in.	7 ft. 6 in.	2nd	11 fms. 3½ in. c.c. + 5½ fms. 3½ in. end links	14½ fms. 3½ in. c.c. + 7 fms. 3½ in. end links
			3rd	21 fms. 2¾ in. c.c. + 6 fms. 2¾ in. end links	29 fms. 2¾ in. c.c. + 6 fms. 2¾ in. end links
3rd 4 compartments	11 ft. 6 in.	6 ft. 6 in.	3rd	9½ fms. 2¾ in. c.c. + 5 fms. 2¾ in. end links	13 fms. 2¾ in. c.c. + 6½ fms. 2¾ in. end links
			4th	19 fms. 2 9/16 in. c.c. No end links	26 fms. 2 9/16 in. c.c. No end links
			4th	22½ fms. 2¼ in. c.c. No end links	31 fms. 2¼ in. c.c. No end links
4th 4 compartments	9 ft. 6 in.	5 ft. 6 in.	4th	8½ fms. 2 9/16 in. c.c. No end links	13 fms. 2 9/16 in. c.c. No end links
			4th	10 fms. 2¼ in. c.c. No end links	15 fms. 2¼ in. c.c. No end links
			4th	14½ fms. 2 in. c.c. No end links	21 fms. 2 in. c.c. No end links
			5th	24 fms. 1⅝ in. c.c. No end links	35 fms. 1⅝ in. c.c. No end links
				PENDANTS FOR 20% RESERVE BUOYANCY	PENDANTS FOR 15% RESERVE BUOYANCY
5th 2 compartments	7 ft. 0 in.	4 ft. 0 in.	5th	9 fms. 1⅝ in. c.c. No end links	11 fms. 1⅝ in. c.c. No end links
			6th	16 fms. 1¼ in. c.c. No end links	19 fms. 1¼ in. c.c. No end links
6th 1 compartment	6 ft. 0 in.	3 ft. 9 in.	6th	8 fms. 1⅝ in. c.c. No end links	9½ fms. 1⅝ in. c.c. No end links
			6th	15 fms. 1¼ in. c.c. No end links	17 fms. 1¼ in. c.c. No end links

Note:—A buoy sometimes has to be of higher classification than its mooring due to depth of water.

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rocker-shackle of the buoy. These reducing-links, however, must never be used by the class of ship for which the mooring is designed. A ship is usually allowed to secure her cable to a buoy if its pendant has a certain specified margin of strength over that of the ship's cable.

The table below gives a list of the different classes of moorings together with the size of ship's cable for which each class of mooring is suitable. The size of cable should always be the standard used when deciding whether a mooring is suitable for a particular ship, because it takes into account the maximum stresses involved at all states of loading, these usually being highest when the ship is at light-load draught owing to the large windage area she then presents.

CLASSES OF MOORINGS

CLASS OF MOORING	CLASSIFICATION BY SIZE OF SHIPS' CABLE							CLASSIFICATION BY DISPLACEMENT
	SIZES OF BUOY-PENDANT. (*All pendants are of wrought-iron except class I (1946) which is of forged-steel*)			SIZES OF SHIPS' CABLE FOR WHICH EACH CLASS OF MOORING IS SUITABLE				
				WROUGHT-IRON CABLE		FORGED-STEEL CABLE		
	DIAMETER WHEN NEW	DIAMETER WHEN WORN TO MINIMUM SIZE ALLOWABLE	PROOF LOAD FOR WORN SIZE	DIAMETER	PROOF LOAD	DIAMETER	PROOF LOAD	
	in.	*in.*	*ton*	*in.*	*ton*	*in.*	*ton*	*ton*
First (1946) ...	4	3½	247·0	4½	211·3	3 1/16	209·7	50,000
First (1922) ... (swinging or head & stern).	4	3 7/8	195·9	3⅞	169·1	2 7/8	192·6	40,000
		3¾	189·8	3¼	161·6	2¾	181·0	
First (1916) ... (light)	4	3½	176·4	2 15/16	141·7	2½	157·5	25,000
Second... ...	3½	3 1/16	149·8	2 9/16	116·7	2¼	127·6	16,000
Third (3-arm)	3	2⅝	120·9	2 5/16	96·3	2	100·8	6,000
Third (2-arm)	2¾	2 7/16	106·9	2⅛	81·3	1⅞	88·6	6,000
Fourth (1934)	2 9/16	2¼	91·1	2	72·0	1¾	77·2	2,500
Fourth (3-arm)	2⅛	2 9/16	86·1	1⅞	63·3	1⅝	66·5	2,500
Fourth... ...	2¼	2	72·0	1¾	55·13	1½	56·8	2,000
Fifth	1⅝	1 7/16	37·1	1¼	28·13	1⅛	31·9	600
Sixth	1¼	1⅛	22·75	—	—	—	—	400

Note :—The dates shown in the 1st column indicate the year in which these moorings were standardised, and they provide a means of distinguishing one mooring from another of the same class.

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In the last column of the table is given the displacement of the largest ship for which each class of mooring is suitable. This is of use when it is required to secure two or more ships abreast each other to a head-and-stern mooring of a heavier class than the one designed for them, but it is emphasised that if any doubt exists as to the suitability of a mooring to be used in this manner the decision should be based on the size of cable rather than on the displacement, because the ships may have a much lighter displacement than normally and so present an abnormally large windage area. To calculate, on the displacement basis, the number of ships which can lie in sheltered water at a head-and-stern mooring, add the displacement of the largest ship to half the displacement of each of the other ships.

Maintenance of Moorings

Moorings exposed to strong tidal streams and rough weather naturally suffer more wear and tear than those in tideless sheltered waters. Head-and-stern moorings suffer little wear and tear compared with swinging moorings. Corrosion, however, particularly in estuaries and in tropical harbours, can cause as much reduction in the weight of the cable as does the wear and tear caused by tidal streams and weather; for this reason moorings at dockyards and bases abroad are usually overhauled at more frequent intervals than those at home.

Moorings at home dockyards are " examined " annually, and " surveyed " at intervals of from two to five years, the interval depending on the class of mooring, the lighter moorings being surveyed more frequently than the heavier moorings. A " survey " entails raising the entire mooring and usually landing it for thorough overhaul and repair, whereas an " examination " is carried out on the spot and without disturbing the anchors. First- and second-class moorings are examined underwater throughout by divers, but only the anchors and the outer 20 fathoms of the ground arms of the lighter classes of mooring are examined by divers, the remainder being disconnected, raised and examined above water in a mooring lighter.

Examination by divers is not so thorough as examination above water, but it is necessary with the heavier classes of mooring because raising them is a major operation, and it is necessary with all classes of mooring to avoid disturbing their anchorages.

At home dockyards the intervals at which the various classes of mooring are surveyed are as follows :—

(i) first- and second-class moorings—every five years ; first-class moorings which have, however, been frequently used by ships equipped with chain cable larger than 3 inch wrought-iron, or the equivalent size in forged-steel, are surveyed every three years ;
(ii) third-class moorings—every three years ;
(iii) remaining classes of moorings—every two years.

Holding-power of Moorings

The forces acting on a ship riding at a mooring are :—

(i) a steady force due to tidal current acting on the underwater hull ;
(ii) the force due to the wind on the above-water surface, which may be steady or fluctuating according as the wind is steady or squally ;
(iii) the sudden snatch loads on the cable, due to the motion of the ship in waves.

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The following table gives estimated values of pulls which ships may exert on their moorings when acted upon by a 60 knot steady wind and a 5 knot tidal stream. It has been assumed that the tide and wind act fore and aft along the ship in each case. This information will give some idea of the holding power required in a mooring. It should be noted that the wind and tidal forces are approximately proportional to the square of the speed in each case and further values can therefore be deduced as necessary for other speeds.

TYPE OF SHIP	AHEAD WIND RESISTANCE. WIND SPEED 60 KNOTS	AHEAD TIDE RESISTANCE. TIDAL SPEED 5 KNOTS	
		HULL	LOCKED PROPELLERS
	tons	*tons*	*tons*
Battleship ...	26	23	14
Fleet Carrier	35	23	18
Light Fleet Carrier	26	16	6
Large Cruiser ...	16	10	9
Small Cruiser ...	11	6	7
Destroyer ...	6	4	5
Frigate ...	6	3	2

It will be seen from the table that when the current is exceptionally strong it might be advisable to trail the propellers.

It should be noted that if the 60 knot wind included gusts up to 85 knots, then the maximum transient wind force on the ship would be approximately double the values quoted. It is then that any extra cable laid out plays an important part by absorbing these shock pulls.

Mooring anchors must be well buried in the sea bed if they are to be effective, and the length of the ground arms must be sufficient to ensure that the pull on the anchor will be horizontal in all conditions of service, otherwise the mooring may drag.

The holding pull of an anchor depends, to a large extent, on its weight, the area of the flukes and the moment of this area about the surface of the sea-bed. It is only possible to get a high holding pull by forcing the anchor to penetrate deeply into the sea bed. The provision of an anchor which is capable of this has been the object of much research in recent years.

In the permanent mooring anchor with a fixed fluke and stabilising stock, it is possible to arrange the fluke below the shank, and separated from it by a certain optimum distance. In this way the fluke digs into the subsoil and develops sufficient pull to drag the shank in also. Consequently, the whole of the anchor contributes towards the holding pull rather than just the fluke, as in earlier designs. The provision of a stock prevents the anchor turning over under heavy load.

The larger the anchor the more strongly must it be constructed to withstand the stresses to which it may be subjected, and the ratio of holding power to weight of an anchor therefore decreases with an increase of its size. The approximate holding powers in reasonably good holding ground of light and

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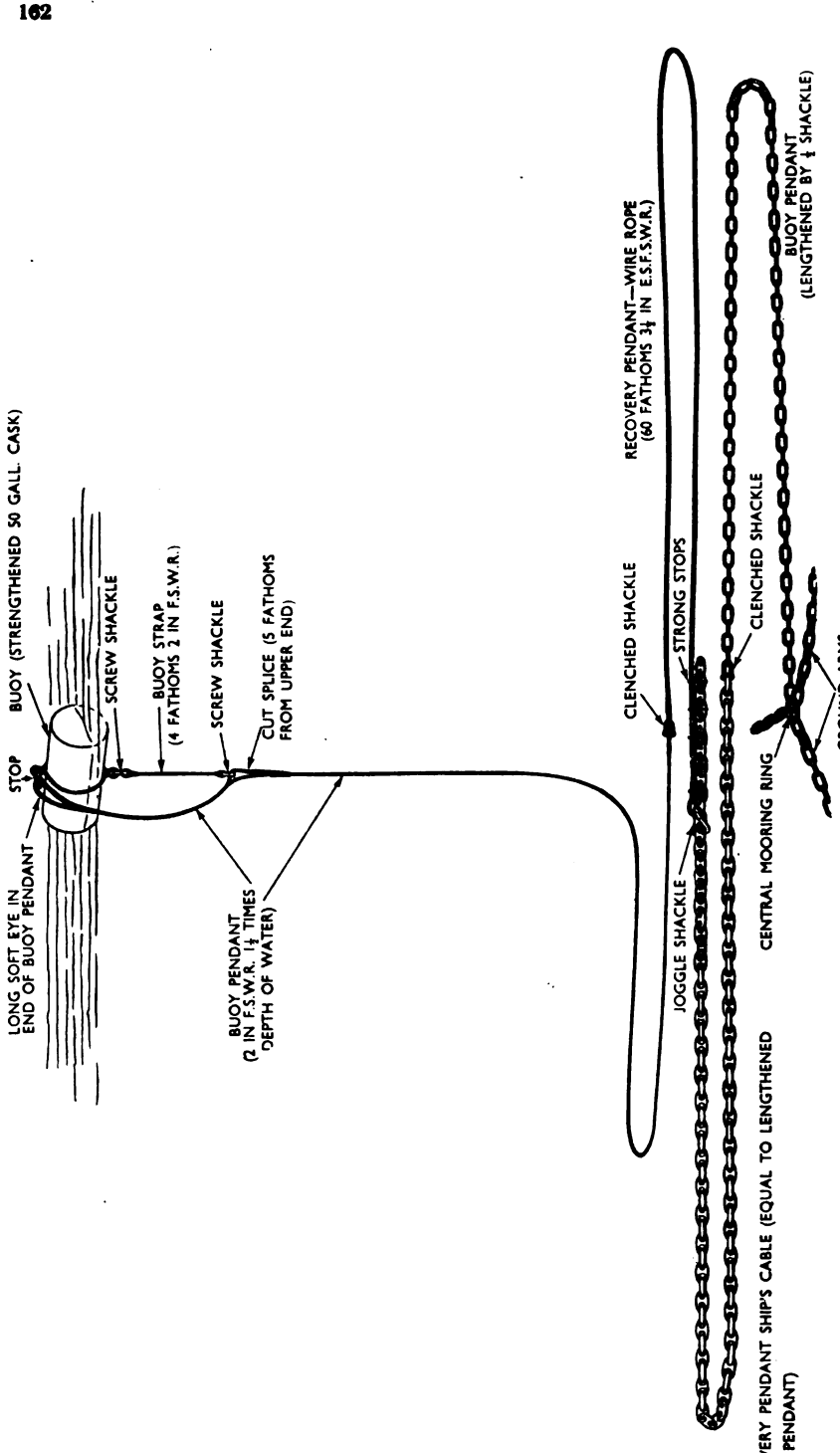
STOP
BUOY (STRENGTHENED 50 GALL. CASK)
LONG SOFT EYE IN END OF BUOY PENDANT
SCREW SHACKLE
BUOY STRAP (4 FATHOMS 2 IN F.S.W.R.)
SCREW SHACKLE
CUT SPLICE (5 FATHOMS FROM UPPER END)
BUOY PENDANT (2 IN F.S.W.R. 1½ TIMES DEPTH OF WATER)
CLENCHED SHACKLE
RECOVERY PENDANT—WIRE ROPE (60 FATHOMS 3¼ IN E.S.F.S.W.R.)
STRONG STOPS
CLENCHED SHACKLE
BUOY PENDANT (LENGTHENED BY ¼ SHACKLE)
JOGGLE SHACKLE
CENTRAL MOORING RING
GROUND ARMS
RECOVERY PENDANT SHIP'S CABLE (EQUAL TO LENGTHENED BUOY PENDANT)

Fig. 36. A swinging mooring fitted for swamping

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heavy anchors of the more common types in terms of their weights are given in the tables on pages 170 and 171.

Hauling-off Moorings

In ports where a strong prevailing wind blows directly on to the berthing jetties, hauling-off moorings are sometimes provided to enable ships to haul themselves well clear of the jetty against the wind when unberthing. They are sometimes also provided in a harbour which is subject to scend, for holding a ship clear of a jetty against her berthing hawsers.

Swamping a Mooring

In an open anchorage which is frequently exposed to the full force of gales and heavy seas, or in one that is subject to a heavy prevailing swell, the buoy of a swinging mooring will not withstand the excessive wear and tear imposed on it. To overcome this difficulty the mooring buoy is removed entirely, and when not occupied the mooring is " swamped " by veering its buoy-pendant to the bottom on a composite recovery-pendant made of wire rope and ship's cable, to which a small but robust buoy is attached by a light buoy-pendant. When the mooring is swamped both the heavy buoy-pendant and its recovery-pendant lie on the bottom with the small buoy watching over them.

Although the weight of the recovery-pendant will tend to keep the buoy in position it must not be assumed that it will always watch over the centre of the mooring. The position of the mooring should therefore be fixed accurately by bearings, or better still by transists of marks on shore, to enable a ship when picking up the mooring to place her bows over its centre, and so reduce the strain on the recovery-pendant as the heavy buoy-pendant is hove up from the bottom.

A second-class swinging mooring used by a light cruiser was fitted for swamping as shown in Fig. 36, and this proved very successful in practice. The heavy buoy-pendant was lengthened to enable its end to be on the ship's forecastle when she was secured. The length of the composite recovery-pendant of cable and E.S.F.S.W. rope enabled the heavy buoy-pendant and the length of cable to be veered to the bottom, by the cableholder and capstan respectively, when the ship was casting off from the mooring. The extra long, light, buoy-pendant enabled the buoy to be recovered over the side of the forecastle when picking up the mooring and before starting to haul up the recovery-pendant.

To pick up a mooring of this type the ship should approach head to wind or tidal stream to avoid drifting, and while heaving in the recovery-pendant her bows should be kept over the centre of the mooring. A boat is sent away with a grass-line, to one end of which is fitted a spring hook, and this is hooked on to the soft eye of the light buoy-pendant. The other end of the grass-line is then led inboard through the hawsepipe and the buoy-pendant is hauled in, the buoy being recovered over the side and its strap unshackled from the pendant at the cut-splice. The light buoy-pendant and as much as possible of the wire recovery-pendant are hauled in by hand, then the wire recovery-pendant is taken to the capstan and hove in until the upper end of the cable recovery-pendant is abaft the slips. The cable recovery-pendant is then shackled to the ship's cable, the wire recovery-pendant is cast off, and cable is then hove in until the end of the heavy buoy-pendant is inboard and lying abaft the hawse-pipe.

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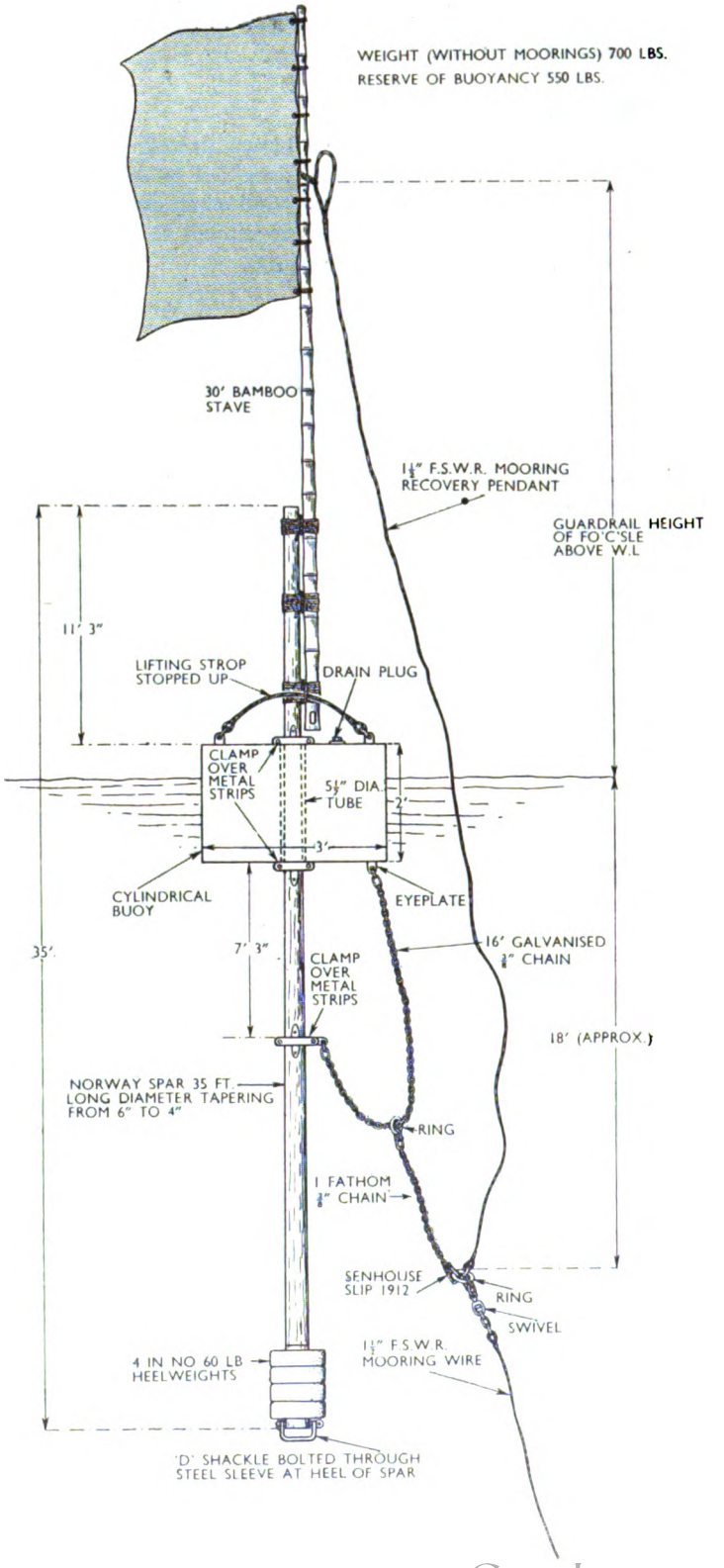

Fig. 37. Standard surveying beacon

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A smaller ship can secure to the same mooring, but with the upper end of the cable recovery-pendant on her forecastle, so that she will ride at a somewhat longer scope than a ship for which the mooring was designed.

To slip from this type of mooring the heavy buoy-pendant is first veered to the bottom by the cableholder ; the wire recovery-pendant is then shackled by a joggle-shackle to the bight of the upper end of the cable recovery-pendant, and it is then brought to the capstan. When ordered by the bridge, the weight is taken on the wire recovery-pendant, and the cable recovery-pendant is unshackled from the ship's cable and its end stopped to the wire recovery-pendant. Meanwhile, the last end of the light buoy-pendant has been led out of the hawsepipe and back over the side of the forecastle, the buoy and its strap have been shackled to the cut-splice, and the buoy has been stopped outboard to the guardrails. The cable recovery-pendant is then veered to the bottom and, when slack, the wire recovery-pendant is taken off the capstan and paid out by hand on the light buoy-pendant to the last few feet of its bight, which is then let go.

Provision of Telephone Cables at Moorings

Certain mooring berths in a port may be provided with telephone or teleprinter cables. For head-and-stern moorings the telephone cables are led from the shore along the bottom, clear of the ground arms, to a separate buoy which is secured to one of the mooring buoys, sufficient scope being allowed in the cables for the tidal range. The ship's telephone cables are then joined to the shore telephone cables on this buoy.

The provision of telephone cables for a swinging mooring is more complicated, however, because the cables are liable to foul the buoy-pendant as the

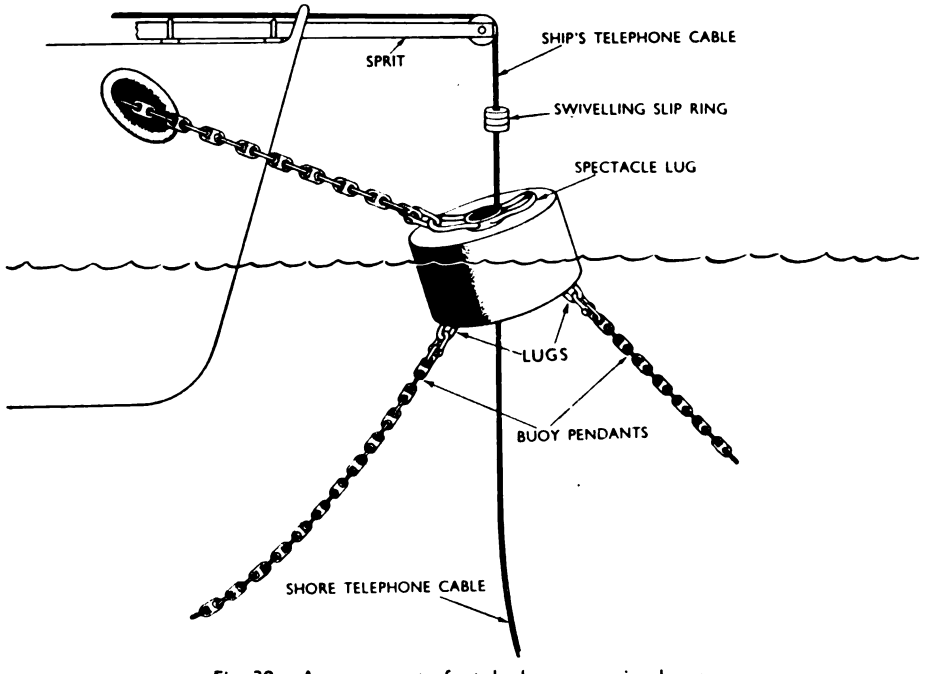

Fig. 38. Arrangement of a telephone mooring buoy

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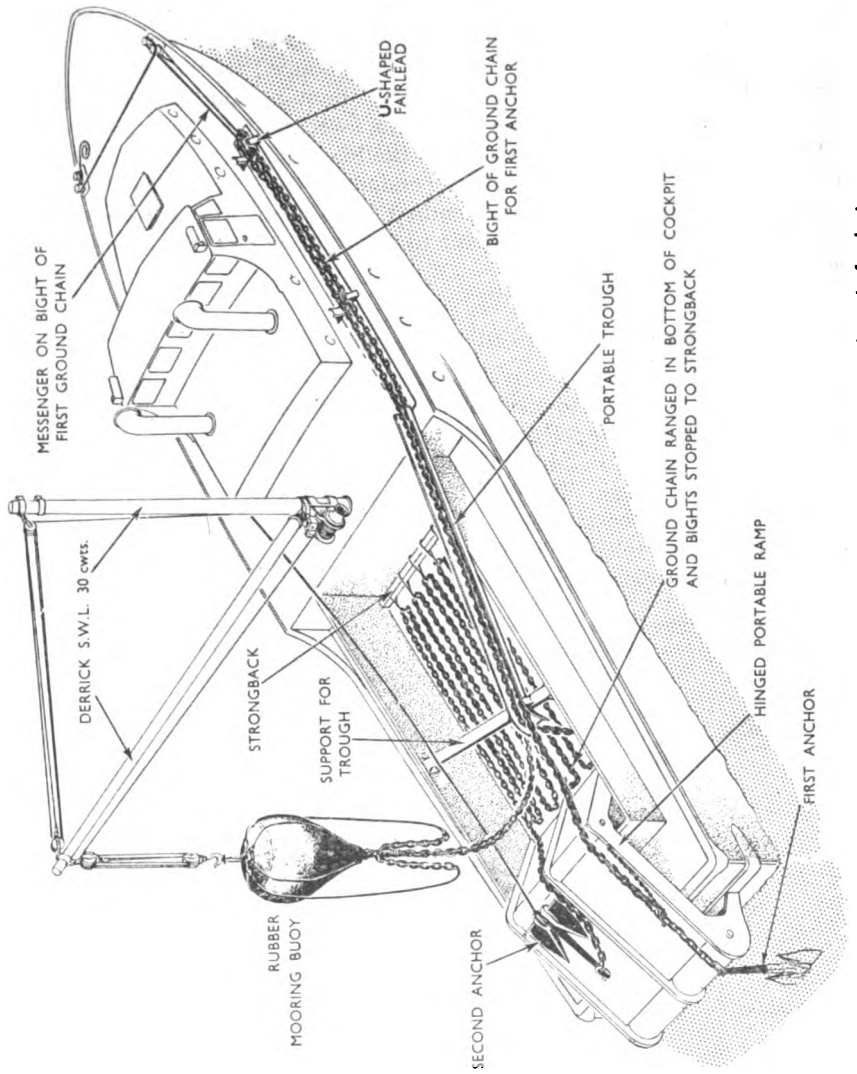
MESSENGER ON BIGHT OF FIRST GROUND CHAIN
U-SHAPED FAIRLEAD
BIGHT OF GROUND CHAIN FOR FIRST ANCHOR
DERRICK S.W.L. 30 cwts.
STRONGBACK
SUPPORT FOR TROUGH
PORTABLE TROUGH
GROUND CHAIN RANGED IN BOTTOM OF COCKPIT AND BIGHTS STOPPED TO STRONGBACK
HINGED PORTABLE RAMP
FIRST ANCHOR
RUBBER MOORING BUOY
SECOND ANCHOR

Fig. 39. Pinnace with anti-snatch mooring embarked and ready for laying

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ship swings round the buoy. In some ports this difficulty is overcome by mooring the buoy with a two-legged bridle to its ground arms, as shown in Fig. 38, thus preventing the buoy from rotating. The ship's bridle is then shackled to a " spectacle-lug " which revolves around a collar fitted to the upper end of the buoy-trunk. The shore telephone cable is led up through the buoy-trunk and is thus clear of the mooring, and the ship's telephone cable is led along a jury sprit of sufficient length to keep it clear of the bridle and plumbing the buoy. The connection between ship and shore telephone cable is made by a swivelling " slip-ring."

Where special provision is not made at a swinging mooring to prevent a telephone cable from fouling the mooring, a special watch must be set to keep it clear as the ship swings.

Laying an Anti-snatch Mooring

Lightweight anti-snatch moorings of the type illustrated in Fig. 35, have been successfully laid in depths of up to 10 fathoms from a R.A.F. general-service, triple-screw, 60-ft. pinnace converted for mooring work by the provision of a few simply made portable fittings. This type of vessel has a crew of six men, is decked in for approximately two-thirds of her length from the bows, has a spacious cockpit aft, and is provided with a Samson-post and derrick capable of lifting 30 cwt.

The following fittings were provided to convert this vessel for mooring work (see Fig. 39). Over her stern was fitted a portable steel ramp incorporating two rollers, which was hinged at the cockpit ceiling so that it could be swung inboard and stowed in the cockpit when not required for mooring work.

A scotchman was fitted on the starboard side of the fore-deck, from the foremost bollards to the cockpit ; two U-shaped fairleads were fitted, one abaft the foremost bollards and the other half-way along the fore-deck ; and a portable trough was provided which led from the fore-deck to the cockpit, where its after end was supported by an athwartships baulk of timber. A steel strongback was fitted athwart the bottom of the cockpit at its forward end for stopping off the bights of the ground chain to facilitate paying it out.

The mooring was made up of two 500-lb. Danforth anchors, two ground arms, each of 15 fathoms of one-inch chain-cable, two drag-chains, each of nine feet of 1¼ in. chain-cable, a buoy-pendant of one-inch chain-cable, and a rubber aircraft mooring buoy. When making up moorings of this nature 300-lb., 500-lb., or 700-lb. Danforth anchors may be used, depending on the locality, the nature of the holding ground and the size and type of craft for which the mooring is to be used, and if necessary the length of each ground-arm may be increased by adding another 7½ or 15-fathom length of cable to its outer end. Forelock anchor-shackles should be used to join the anchors to their ground arms, and the inner ends of the ground-arms to the buoy-pendant ; their use facilitates breaking the ground-arms when the mooring is weighed. The ends of the two inner drag-chains should be stopped together by a light lashing before the mooring is laid ; this ensures that the anchors are laid at the correct distance apart ; the lashing should soon disintegrate after the mooring is brought into use. The length of the buoy-pendant should be three fathoms less than the maximum depth of water over the mooring to allow full effect for the anti-snatch properties of the mooring.

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The mooring was embarked in the reverse order to that in which it was to be laid. The second anchor was first placed on the ramp, crown uppermost, and then lashed down ; then its ground-arm was shackled to it and a lowering messenger was secured to its crown by means of a strop and toggle. The second ground-arm was then ranged in flakes along the bottom of the cockpit, the forward bight of each flake being securely stopped to the strongback. The buoy was lashed on the fore-deck before the foot of the mast and shackled to its buoy-pendant. The buoy-pendant was then flaked down in the cockpit and its lower end shackled to the inner ends of the ground-arms. The first ground-arm was then flaked down in the cockpit in the same way as the other ground-arm until there remained a length equal to that of the depth of water in which the mooring was to be laid. This remaining length was then ranged in a bight in the trough, along the fore-deck to the foremost bollards, and back again over the cockpit to the ramp, where its end was shackled to the first anchor ; round the forward end of this bight was rove a messenger which was belayed to the foremost bollards. The first anchor was slung a'cockbill from the ramp on a Blake-slip.

The boat then proceeded to the position of the mooring, which had previously been buoyed. Buoying the position is not necessary if marks on shore suitable for transits and bearings are available, but if a mark-buoy is laid its mooring should be well clear of the area where the main mooring is to be laid, otherwise the two may foul each other.

When laying a two-arm mooring the upstream or weather anchor is always laid first, and the pinnace was accordingly manœuvred upstream of the position for the first anchor, stern to the tidal stream and with her engines stopped. When over the position for the first anchor the Blake stopper holding the anchor on the ramp was slipped and the anchor lowered to the bottom by means of the messenger rove around the bight of its ground-arm. The messenger was then unrove and the remainder of the first ground-arm paid out from the cockpit, each successive lashing being cut as the cable tautened to ensure that the ground-arm would be laid out straight along the bottom. When the lower end of the buoy-pendant was out of the cockpit and on the ramp the lashings of the buoy were cut and it was hove overboard. The second ground arm was then paid out in the same way as the first, and finally the second anchor was lowered to the bottom on its messenger, the messenger being then slipped by means of its toggle. To ensure that the ground-arms are laid out taut and straight it may be necessary, especially in a strong wind or tidal stream, to give a kick ahead on the engines now and again, and also just before the second anchor is laid.

After the mooring is laid its holding power can be tested by securing the stern of the vessel to the buoy with her towrope and putting her engines ahead while keeping her heading along the direction in which each ground arm was laid. This test will also serve to embed the anchors.

When raising this type of mooring the buoy should first be recovered over the stern of the vessel and the buoy-pendant be hove in until the inner ends of the two ground-arms are inboard. The two ground-arms can then be unshackled and each anchor be weighed by its own ground-arm. If the depth of water is too great for this, however, the buoy must be unshackled from its pendant and the mooring lowered to the bottom where a diver can unshackle the two ground-arms ; the ends of each ground-arm can then be recovered and each anchor be weighed by its ground-arm.

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Laying a Resilient Three-arm Mooring

Heavy moorings are laid by a specially built, self-propelled, mooring lighter which is equipped with a derrick, capstans and winches, and provided with sufficient deck and hold space to accommodate the ground tackle. The crew of the vessel includes blacksmiths for clenching the shackles, and divers for inspecting the mooring when it has been laid.

As much of the mooring as possible is assembled and joined up on shore; it is then embarked in the mooring lighter in the reverse order to that in which it is to be laid. The lighter then proceeds to where the mooring is to be laid and buoys the position for its centre. She then drops her bower anchors at this position, moves astern along the direction of the first arm to the position where the first anchor of the mooring is to be laid, and lays out two kedge anchors to hold her stern. The first mooring anchor is then shackled to its mooring chain and lowered on its gravity-band to a depth of from 5 to 16 feet above the bottom, whence it is slipped. The lighter then hauls ahead on her bower cables to the central position, and at the same time tautly and evenly lays out the first arm of the ground-chain.

The first arm is shackled to its clump and to its central span, and these, together with the central ring and central spans of the other two arms, are then lowered to the bottom and buoyed.

The lighter then weighs her two kedge anchors and re-lays them at the position for the second mooring anchor; she then returns to the central position and recovers the central ring and central spans. The end of the second arm with its clump is shackled to its central span, the clump is lowered to the bottom, and the end of the third central span is buoyed. The lighter then hauls astern on her kedge anchors, at the same time tautly and evenly laying out the second arm of the ground-chain; to the end of this second arm is shackled the second mooring anchor, which is lowered and dropped in a similar manner to the first, tension being kept meanwhile on the ground-chain.

The lighter then weighs her two kedge anchors and re-lays them at the position for the third mooring anchor. She then returns to the central position, and recovers the end of the third central span and the central ring. The buoy-pendant is then joined to the central ring and the third central span is joined to the third mooring arm; the mooring buoy is then hoisted out and the lighter hauls herself along the direction of the third arm, the clump and ground-chain being laid in the same way as was the second arm. Finally the third mooring anchor is laid, after which divers are sent down to examine all connections and to see that the mooring anchors are properly embedded.

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HOLDING POWER OF SHIPS' ANCHORS

TYPE OF ANCHOR	REMARKS	WEIGHT OF ANCHORS IN CWT.			
		1	20	60	100
		MAXIMUM ANCHOR PULL IN TERMS OF ITS WEIGHT			
Admiralty Standard Stockless (A.S.S.).	The figures apply equally to anchors of similar design, such as Hall's, Byer's and Taylor's. The anchor seldom buries more than the flukes, the large crown and shank preventing further burial. All these designs are unstable, that is, under load the anchor will rotate about the shank and pull to the surface of the sea bed. It may not re-trip, in which case the anchor pull will be reduced to about one-third of the maximum values quoted.	3½	3½	3½	3½
Admiralty Plan, fixed fluke, stocked anchor.	Used for boats' and kedge anchors. Stable under load and maintains its maximum pull.	3	3	3	3
Danforth Anchor	Generally used in small craft. The anchor is stabilised by a large stock, but will be unstable if the shank is bent; this may occur under a yawing pull. It sometimes fails to trip on soft mud where the weight of the stock and crown may sink this end of the anchor and leave the points standing clear. The small tripping lugs of this design fail to prevent this. A good anchor in sand and shingle.	40–50	15	8	7*
CQR (Secure) ..	A good anchor in small sizes, especially where it can be manhandled; it is particularly suited to small boats. Partially unstable.	20	10	7	—
Admiralty Cast Type 10. (A.C.10).	This anchor has been designed for warships, and is best suited for anchors of over one ton in weight. It is quite stable and will maintain full holding pull if dragged. *Note*: An improved version, A.C.11, slightly more efficient than A.C.10, is being manufactured for ship trials (1953).	—	10	7½	7*

*These figures are estimates as these designs have not yet been tested in these weights.

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HOLDING POWER OF PERMANENT MOORING ANCHORS

TYPE OF ANCHOR	REMARKS	WEIGHT OF ANCHOR IN CWT.		
		36	72	110
		MAXIMUM ANCHOR PULL IN TERMS OF ITS WEIGHT		
Pick .. .. (existing type).	Easily laid. Bites quickly ..	2	2	2
Admiralty Mooring Type 7. (A.M.7).	Needs more care in laying than the Pick Type. Must be dragged into the bed after dropping and before the ground chain is coupled up to ensure full anchor pull.	5	5	4*
Admiralty Mooring Type 11. (A.M.11).	This design needs to be dragged about one shank length after initial dropping and before the ground chain is connected up in order to get full anchor pull. *Note:* An improved version, A.M.12, has been designed and partly tested. It is estimated to give 25 per cent. more pull than A.M.11. Full-scale tests have not yet been completed (1953).	10	9	7*

*These figures are estimates as these designs have not yet been tested in these weights.

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CHAPTER IX

Salvage Operations

THE SALVAGE of a ship, particularly one which is sunk, or stranded and severely damaged, is usually a complicated operation only to be carried out by specialist salvage officers and with special equipment. Some salvage operations are, however, well within the capabilities of a resourceful seaman using the normal equipment of a well-found ship or the equipment obtainable at any port. The purpose of this chapter, therefore, is to provide the seaman with an elementary knowledge of the methods and requirements of ship-salvage, and so enable him to undertake its simpler forms, or in complicated cases to take such " first-aid " measures as will simplify subsequent salvage operations by experts or even prevent the total loss of the ship.

Some Legal Aspects of Salvage

It is, of course, the duty of every seaman to afford every possible aid to vessels in danger, in distress or in want of assistance, and to save life. When property, such as the ship or her cargo, is also saved the salvor or his employer is usually entitled to claim recompense in the form of a salvage award commensurate with the degree of assistance rendered and the value of the property saved.

If the vessel is in immediate danger or dire distress any such aid will obviously be welcomed by her master and crew, and accepted without demur ; but if the vessel has not been abandoned and if she or her crew are not in immediate danger it is usual for her master or owner to come to some form of agreement with the prospective salvor in regard to the degree of assistance required. When offering his services the prospective salvor should bear in mind that salvage awards are made only when the services rendered are successful or have materially assisted in the saving of property, and that no claim can be entertained if the efforts are unsuccessful; moreover, wrongful methods of salvage resulting in further damage or loss of property, or even the loss of the ship, may render the salvor liable in respect of such damage or loss.

It is therefore very important that full agreement on methods to be adopted should be reached between the salvor and the master or owner of the vessel, but it should be remembered that the master is at all times responsible for his ship and her cargo, and that a salvor has no right to give him orders. At the same time it may be presumed that if the master has asked for assistance he is willing to accept advice and to co-operate.

General instructions to naval officers in regard to offering salvage assistance, and the procedure in claiming salvage awards for such services, are laid down in the *Queen's Regulations and Admiralty Instructions*, and the following remarks are given in amplification of these instructions.

Before starting operations the prospective salvor should, if possible, board the vessel and consult with her master, who should be requested to sign *Lloyd's Standard Form of Salvage Agreement*. If this is impracticable every endeavour should be made to make it clear to the master that this agreement is to apply and that the form will be signed as and when convenient. The agreement is usually accepted in its " open form," that is to say the remuneration payable in

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the event of salvage being successful is open to arbitration, and that the basis of agreement is " no cure, no pay." In the case of a vessel abandoned by her crew this matter does not arise.

Any reports rendered during salvage operations should be carefully worded, because many interests are concerned in marine casualties, and the insurance markets react strongly to such reports as may be published. Whoever is in charge of salvage operations should therefore confine himself strictly to details of damage and to the existing situation, and he should avoid any predictions.

First-aid to Vessels Afloat

A vessel at sea which is so damaged that she requires assistance will probably require to be towed to port, but before taking her in tow the extent of her damage should be examined and its effect on her seaworthiness should be considered. If the damage is considerable and the nearest port with good repair facilities is some distance away it is preferable to tow the vessel to the nearest safe anchorage as quickly as possible and there make temporary repairs before attempting the long passage. This may seem obvious, but ships have in fact been lost because this elementary precaution has been neglected.

If the vessel is leaking badly she should be beached, because her seaworthiness will rapidly deteriorate as she loses her buoyancy. Also, the deeper a ship sinks in the water the greater will be the water-pressure on the leaks and exposed bulkheads, and should the latter collapse under the increased water-pressure the vessel will probably sink.

Pumps and the confinement of Flooding

During preparations for towing, all available portable pumps should be transferred to the vessel, even if their immediate need is not apparent ; it is far better to have the pumps at hand and find eventually that they are not needed, than to have to stop towing for them to be transferred when an emergency arises. If the vessel has electric pumps and her electric generators are out of action, the practicability of providing her with electric power from the rescue ship should also be considered. A quick general survey of the vessel should then be made, flooded compartments should be noted, and immediate steps taken to ascertain whether the leakage is likely to be within the available pumping capacity.

Generally speaking, it is advisable to concentrate on confining the flooding to as few compartments as possible, and where difficulty in pumping any badly damaged space is anticipated it is best to concentrate on preventing any extension of the damage to surrounding spaces. The compartments to be dealt with first will therefore be those with the least leakage, because conditions will improve with every ton of water pumped out. These comparatively small leaks should be promptly dealt with so that the available pumps can be concentrated as soon as possible on the more extensively damaged sections, with the object of restoring the maximum amount of buoyancy.

Having ascertained the nature and extent of the damage, those compartments which are leaking should be inspected to see whether they can be tightened up and reclaimed. Continuous soundings should be taken in all compartments, even though they are remote from the damage, so that early warning of any increased leakage may be obtained. Pumps should be rigged with the shortest suctions possible so that they discharge overboard by the most direct route.

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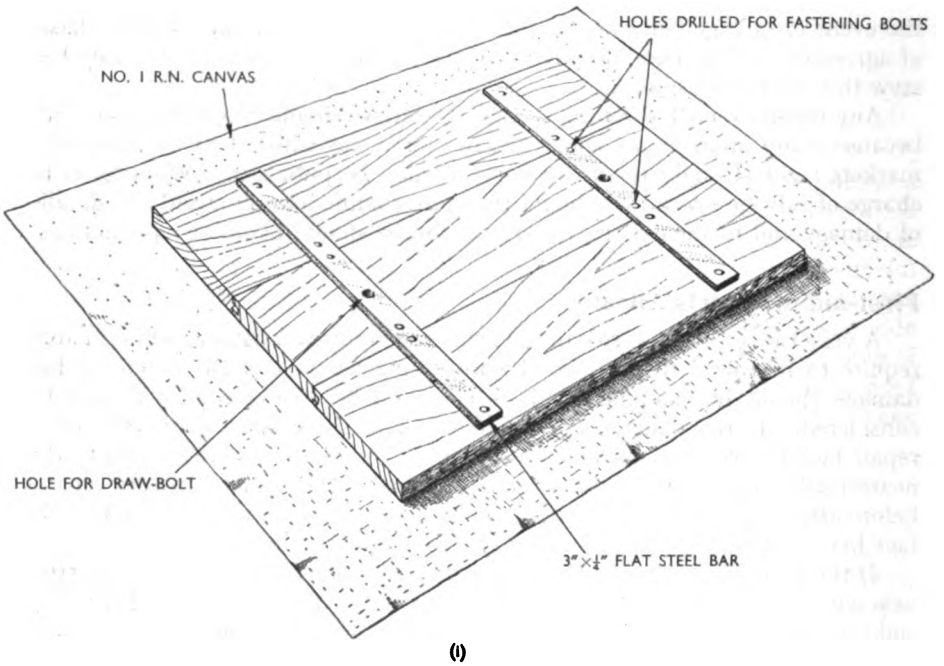
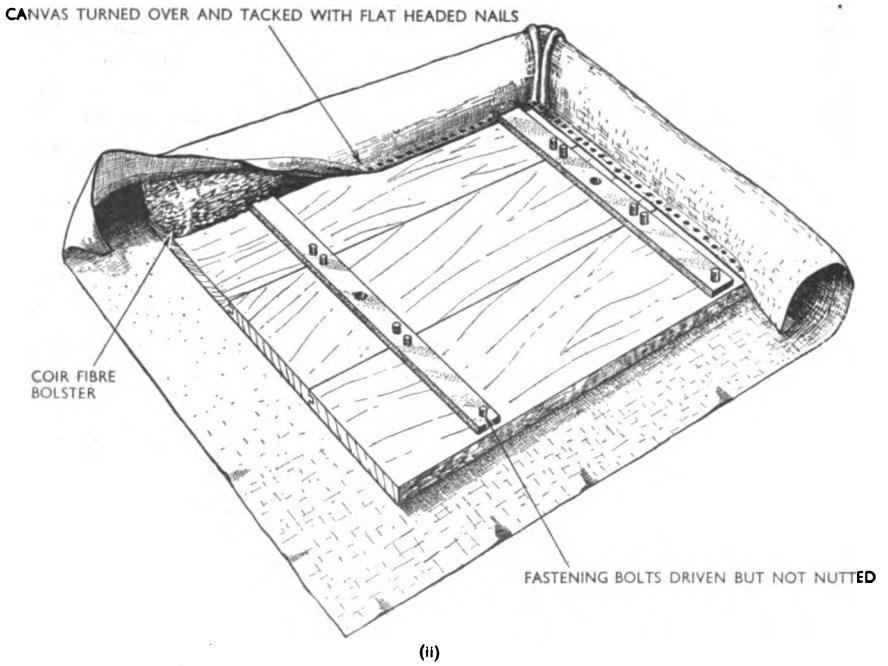


(i)



(ii)

Fig. 40. Construction of a wooden pad for patching a small hole

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It is always advisable to attach a stout line or a light purchase to the end of the suction-pipe so that it can easily be lifted and cleared if it gets choked. Any leaks which can be got at should be stopped with wooden wedges, plugs, tallow, etc., and all pumps should be concentrated on the badly damaged compartments as quickly as possible.

The amount of water, in cubic feet per second, which will enter a ship through any hole in her bottom can be estimated from the formula $0{\cdot}62\ a\ \sqrt{2gH}$, where a is the area of the hole in square feet, g is 32·2 and H is the depth of the hole below the surface.

Remarks on Leak-stopping

Temporary measures.—It is often impossible to get at leaks in the holds of a merchant ship because of the cargo there, and temporary measures have then to be adopted to stem the inflow of water until more permanent repairs can be effected by divers at the nearest sheltered anchorage. To stop small leaks in seams or rivet-holes, bundles of oakum secured to a bottom-line with split-yarn and hauled under the ship and over the leak will often prove effective; the suction draws the oakum into the leaks and water-pressure holds it there so long as the compartment is kept pumped out. For larger leaks blankets and mattresses backed by wooden battens dogged to bottom-lines and then hauled into place will often prove effective.

As soon as the vessel has been anchored or beached in a sheltered spot, consideration should be given to replacing these temporary measures by more permanent repairs and to make the vessel as seaworthy as possible.

Constructing and fitting a small patch.—The construction of large patches to cover extensive damage is usually beyond the resources of the seaman on the spot, but he should be able to make small patches with the means at his disposal to cover less extensive damage. The construction and fitting of a simple wooden pad suitable for patching a small hole is described below and illustrated in Figs. 40–42.

The materials to be used in the construction of patches depend largely upon what is available on the spot at the time. Tongued and grooved timber is most suitable, but not essential, A useful guide to the thickness of timber required to stand up to a given pressure can be obtained from the formula :—

$$\text{thickness} = 3\sqrt{\frac{L \times \frac{1}{2}P \times 0{\cdot}015}{B}}$$

where :—

L is the length in feet between the supporting surfaces on the hull structure;

P is the total pressure on the pad in pounds per square inch; and

B is the breadth of the pad in inches.

Having selected the timber necessary for the work the following additional materials will be required :—

(i) two 3-in. × ¼-in. flat steel bars, equal in length to the breadth of the patch;

(ii) two 3-in. × 3-in. steel angle-bars of similar length;

(iii) two angle-bars (to act as strongbacks) fitted with long draw-bolts;

(iv) sufficient canvas to cover an area approximately five feet longer and wider than the patch;

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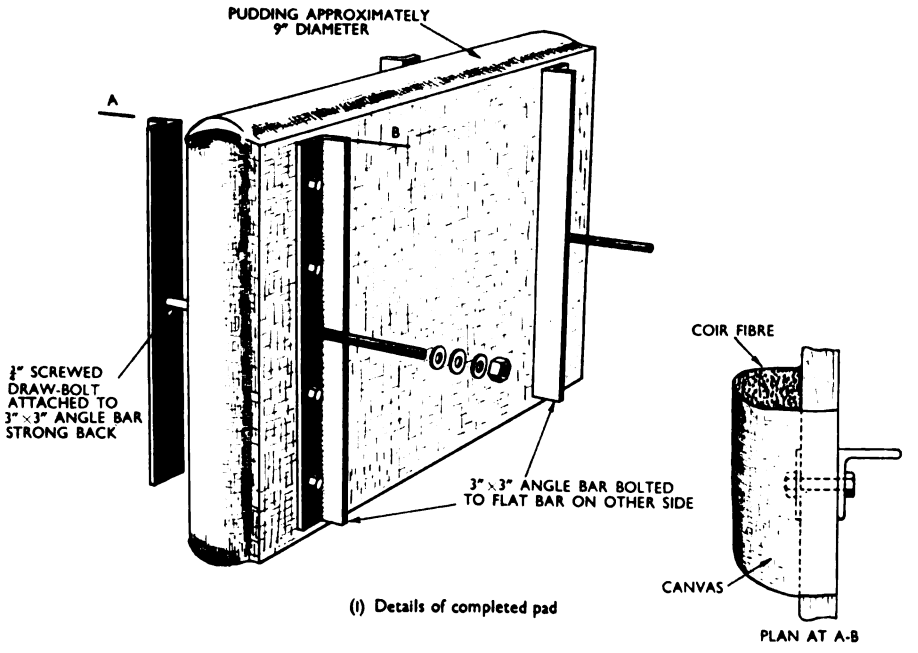
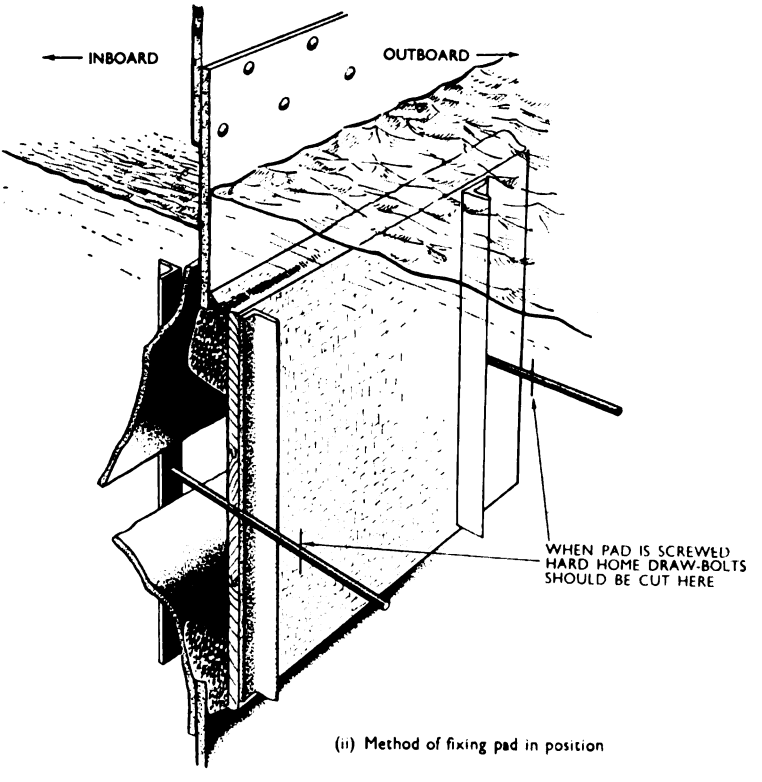


(i) Details of completed pad



(ii) Method of fixing pad in position

Fig. 41

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(v) a quantity of coir fibre for use as a pudding around the edges of the patch. (Oakum can be used instead of coir fibre but is not so satisfactory as it has no spring when compressed.)

The canvas is first stretched out on the deck and the timber is then cut and laid centrally upon it so as to leave a 2-ft. 6-in. margin of canvas all round, as shown in Fig. 40 (i). The two flat bars are then laid in position across the planks of timber, and holes are drilled through each bar and plank (two to a plank) and through the canvas backing so that the bars and planks can be firmly secured to each other by steel bolts.

If the pad is to be secured in place by draw-bolts the holes for these are now drilled through the bars, timber and canvas ; the holes should be large enough to allow for the wood swelling under water, otherwise it will nip the bolts and make it impossible to adjust them when fitting the pad in its correct position.

The two 3-in. × 3-in. angle-bars are now drilled in a similar manner, using the flat steel bars as templates. The flat bars are then placed on the timber and the securing-bolts driven through. Coir fibre is now teased out and laid so as to form a pudding-bolster nine inches in diameter around the edges of the patch, and the canvas is then turned over this and tacked down with flat-headed nails, as shown in Fig. 40 (ii).

The pad is now turned over, canvas side uppermost, the two 3-in. × 3-in. angle-bars are fitted in place over the protruding bolt-ends, and the bolts are nutted and screwed home, thus completing the pad as shown in Fig. 41 (i).

The two strongbacks, cut to the required length, are now fitted with their respective draw-bolts. The hole for the draw-bolt should be drilled slightly nearer to one end of the strongback than the other, so that the strongback will hang vertically when it is pivoted on the draw-bolt. Fig. 41 (i) shows the pad complete with its draw-bolts and strongbacks, and Fig. 41 (ii) shows the pad fixed in position.

A pad of this type, however, will probably float when placed in the water, and it must therefore be ballasted so that it can be slung over the side and lowered into position. The weight of ballast required is very simply calculated as the following example shows.

Example :

Timber—8 ft. × 3 ft. × 2½ in.	= 5 cu. ft.	= 180 lb.
Pudding—22 ft. × 9 in. × 9 in.	= 9 cu. ft.	= 12 lb.
Angle-bars—say		= 50 lb.
Total volume and weight of pad	= 14 cu. ft.	= 242 lb.
Weight of water displaced by pad if entirely submerged ...	= 64 × 14	= 896 lb.
Actual weight of pad		= 242 lb.
Weight of ballast required		= 654 lb.

Draw-bolts with angle-bar strongbacks provide the most efficient method of securing the pad in position when the hole is long and narrow, or where the plating is light and the frames widely spaced. But over a round hole, particularly one with its edges jagged and bent inboard, the pad will have to be secured in position with hook-bolts as described below and illustrated in Fig. 42.

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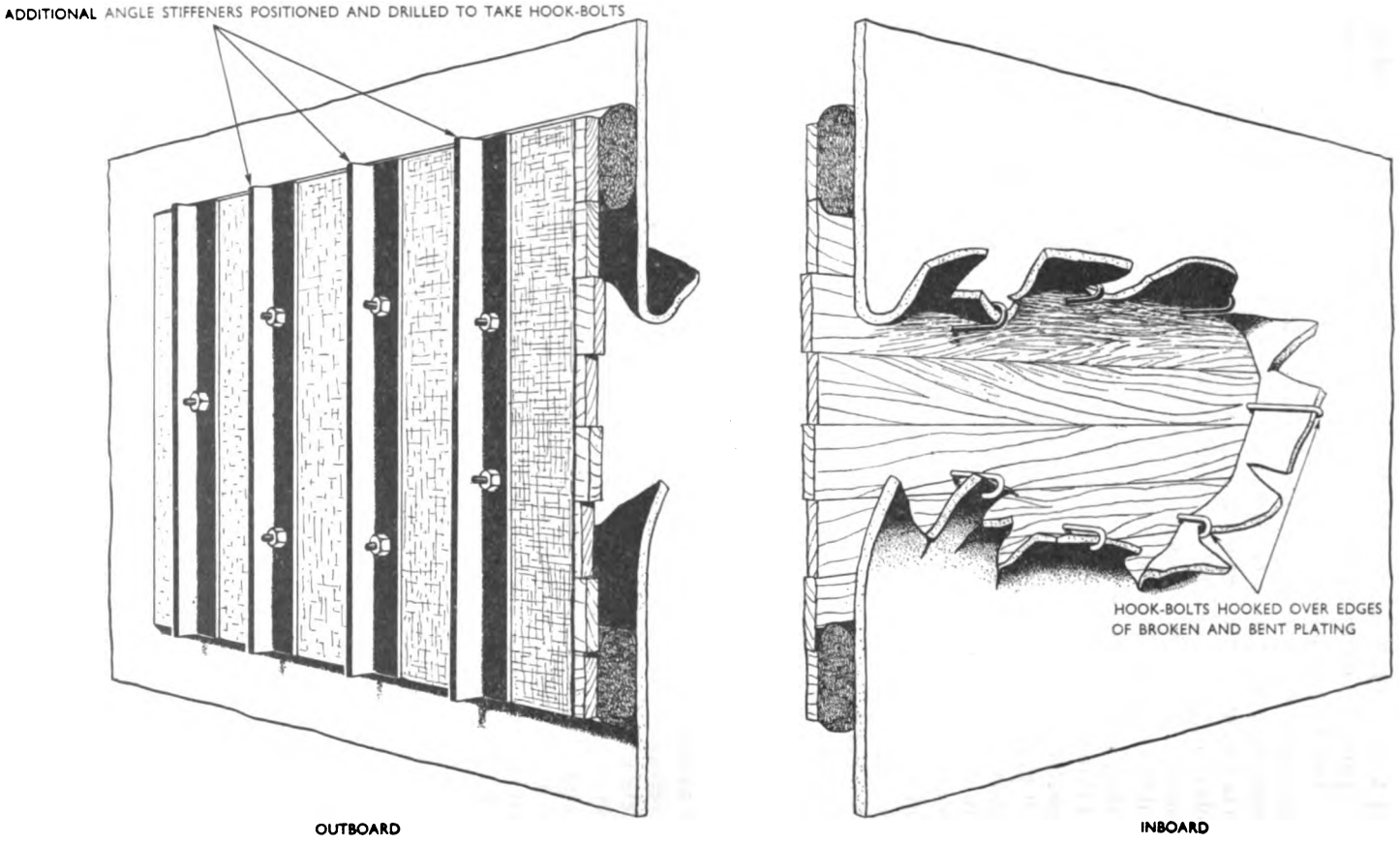
ADDITIONAL ANGLE STIFFENERS POSITIONED AND DRILLED TO TAKE HOOK-BOLTS
OUTBOARD
HOOK-BOLTS HOOKED OVER EDGES
OF BROKEN AND BENT PLATING
INBOARD

Fig. 42. Pad fitted with stiffeners and secured in place by hook-bolts

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To fit the pad with hook-bolts the outline of the hole is drawn on the canvas backing, and holes for the hook-bolts are drilled through the timber at suitable intervals round, and well within, the indicated perimeter of the hole. The holes should be large enough to allow the hook-bolts considerable play so that when the pad is in position the hooked ends of the bolts can be placed as required. Such a pad will probably require stiffeners which should be fitted to the outside of the pad and in such a manner that they are held in place by the hook-bolts.

Use of Concrete

Concrete, which is a composition of cement, gravel and sand mixed with water, is used extensively in salvage work for temporary repairs and leak-stopping, particularly where the work has to be done by divers and where there is no inflow of water through the leaks; in a submerged compartment, for example, which has been flooded up. It is also of particular value in repairing damage to the bilges of merchant ships where the frame-spaces between the margin-plates and the bottom-plating can be filled and there is no need to construct boxes to hold the concrete until it sets.

In salvage work "Ciment Fondu" is preferable to ordinary "Portland" cement because it sets more quickly and so will withstand water-pressure in a shorter time; good results can, however, be obtained with Portland cement, but the two should never be mixed. Cement by itself has very little strength and so it must be mixed with coarse and fine "aggregate" in fixed proportions to make concrete. (Aggregate is a term used in the building trade to describe broken stones, gravel and sand; in this context coarse aggregate is gravel of $\frac{3}{8}$-in. to $\frac{3}{4}$-in. gauge and fine aggregate is sand.) For ordinary concrete work the proportions by volume are one of cement to two of fine aggregate and four of coarse; but for underwater work it is desirable to increase the proportion of cement used, and a good mixture for such purposes is one of cement to $1\frac{1}{2}$ each of fine and coarse aggregate by volume; this provides a quick-setting mixture which will give satisfactory results in a shorter time than that used for ordinary building purposes.

To make concrete the cement and aggregate are well mixed, and water is added until the mixture is of a consistency which can be easily worked into the corners and crevices of the space to be filled. In deciding on the quantities of materials required for a job it must be remembered that the volume of the mixture will be reduced by approximately 30 per cent. when water is added during mixing. For quicker hardening, warm fresh water with a little soda added will help, but it is not essential.

When sending a mixture down to a diver care must be taken to prevent the cement from being washed out so that only sand and gravel remains when it reaches him. It is best to send the mixture down in buckets or canvas bags, but if large quantities are required a chute may have to be used; when using a chute the mixture should be sent down in large quantities at a time and not in dribs and drabs.

Where there is no support for the mixture a rough timber box should be constructed and firmly fixed around the space to be filled. Materials sectionally large enough to support the weight of the mixture must be used until it sets, and it should be borne in mind that when dry the aggregate weighs approximately 30 cwt. per cu. yd. and the cement approximately 23 cwt. per cu. yd.; it will therefore be seen that stout timber, well shored and supported, will be required.

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To close gaping fractures with cement the first of the mixture is usually sent down to the diver in bags, which are then " middled " and wedged in the fracture with half of them outside. When the aperture is thus closed the remaining space is filled in and the whole then shored up. If a large space is to be filled in, much time and material can be saved by packing it with handy sized pieces of rock, but care must be taken to ensure that they are well bonded into the concrete.

To stop small leaks with concrete while they are still under pressure the leakage must first be reduced to a minimum by plugging, and then a drain must be provided to carry away the water until the cement is set. A rough water-course should be constructed in the ship's bilges from the damage to the limber-holes, and for boxes a drainpipe or pipes should be provided. The cement is then applied in the usual way, time being allowed for it to set ; it is then well shored and the drains are securely plugged.

If large cement boxes are being constructed over the inside of temporary patches to provide additional strength for long sea passages, or against damaged bulkheads for stiffening them, additional reinforcing with odd sections of steel will greatly add to their strength.

Concrete is of little use for a fracture which is liable to " work " in a seaway. It does not bind well with steel which is contaminated with oil, and is most satisfactory on lightly rusted surfaces. If there is any likelihood of grease or oil on a surface which is to be covered with concrete, the surface should, if practicable, be cleaned with petrol or a hot solution of soda.

Use of Compressed Air

Compressed air is extensively used in salvage operations for driving under-water tools, pumps and other equipment, and it can also be used in certain circumstances to recover buoyancy in flooded compartments which cannot be pumped out. By sealing the flooded space and introducing air under pressure the water is forced out through the fractures and so buoyancy is restored. The use of compressed air for this purpose in merchant vessels (except in oil tankers) is limited, because their cargo-holds have large hatches and numerous openings which can only be sealed by very extensive work. In cargo-vessels therefore, compressed air is only of use in tanks and spaces which are constructed as dry tanks, ballast tanks and oil tanks.

Compressed air can be of considerable value for recovering buoyancy in double-bottom tanks which have been damaged by grounding, but it should be used with discretion, because building up sufficient pressure in the tanks to expel the water exerts a considerable strain on the tank-tops. The tank-tops of merchant vessels are constructed and tested to withstand a pressure-head of water equal to that on the bottom-plating when the ship is fully loaded, so theoretically there should be no risk of damage in building up such an air-pressure ; in a ship with heavy bottom-damage, however, it should be assumed that the tank-top also may be strained and weakened, and so it must only be submitted to any additional stress with great care. The ship may also be floating at a greater depth than is normal owing to flooding, and if, therefore, it is considered that there is any risk of damage to the tank-top by the use of compressed air it should be well shored. In the holds of a fully loaded vessel the risk of damage will be greatly reduced as her cargo will help to prevent any tendency for the plating to lift when air is forced into the tanks. The usual

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method of admitting compressed air into a double-bottom tank is by means of a flexible pipe tightly fixed into a wooden plug, which is driven into the " breathing-pipe " of the tank. If possible, a pressure-gauge should be provided to indicate immediately if the air-pressure is excessive or the water is not being freely displaced.

Oil tankers, with their numerous easily sealed compartments, are particularly suitable for the use of compressed air. The tank-lids are so constructed that they are air-tight when closed. There are valves which can be closed in the gas pipelines, and the oil compartments are virtually sealed whenever they are filled. In some tankers a convenient method of admitting the air is to use the tank " steaming-system " (a system used to admit steam to the tanks when cleaning them); by disconnecting the pipeline and connecting the air-compressors to it the compressed air can be admitted simply by opening a valve. This practice was widely adopted during the Second World War, and some tankers were fitted with portable air-compressors in the forecastle, the necessary connections being provided to enable air to be pumped in both from the starting-air-compressors in the engine-room and from the portable compressors.

Aid to Vessels Beached or Stranded

Beaching a Vessel

If a vessel is so heavily damaged that the leakage cannot be brought under the control of the available pumps she should be beached on the nearest shore. If there is any choice of beach the one selected should have a firm bottom with a gentle slope, be clear of rocks, and be free of strong currents and scouring, but it is generally better to beach anywhere than to run the risk of sinking in deep water by attempting to reach a good beaching-place.

The vessel should, if possible, be beached stern to and as nearly as practicable at right angles with the shore, and in line with the direction in which she is to be hauled off. The advantages of such an attitude are that her bows, which are the strongest part of her hull, will face the force of any waves generated by an onshore gale, she will present the minimum area to the pounding of any onshore waves, her ground-tackle is readily available for securing her in position, and she is in the best attitude for hauling herself off or being hauled off. If it is not possible to beach the vessel stern to shore, then she should be beached bows to shore but otherwise in a similar attitude to that described above.

In tidal waters, and when circumstances permit, it is better to allow the vessel to ground on a falling tide than to drive her onto the beach. How far up she is beached depends upon many matters, such as the range of the tide, whether it is necessary for the damaged places to be uncovered at low water, and the time it will probably take to repair the damage; but the vessel should not be beached too far up, otherwise refloating her may be unduly delayed or become a major operation.

Securing a Beached or Stranded Vessel

When a vessel is beached or stranded the first task is to secure her so that she will not be driven further onshore by the tide or bad weather, not suffer further damage by pounding in a swell or in heavy seas, and not be slewed broadside on to the waves.

A vessel is best secured with her anchors and cables laid out with as much scope of cable as possible and backed as necessary by other ground-tackle. It

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is emphasised that any ground-tackle used should be as heavy and as strong as possible and laid out with as much scope as possible, because the stresses to which it will be subjected are far greater than normal for the reasons described below.

When a vessel is riding normally to her anchor in a heavy sea she is not forced to leeward by the waves but merely rises and falls on each wave as it passes her; as she rises on the crest of each wave she will surge ahead a little and then drop back as she falls in the trough; this surging, combined with the spring in the bight of the cable, prevents sudden and heavy stresses being transmitted to her anchor. When waves break against a vessel aground in shallow water, however, they exert a considerable force, tending to push her farther shoreward, and to prevent this the cables of any ground-tackle holding her must be hove as taut as possible; there is then no bight in the cables to absorb any sudden stresses. Furthermore, that part of the vessel which is seaward may be waterborne and so may tend to rise and fall with the passing of each successive wave, but because the vessel is aground she cannot surge, and so the extra stress is transmitted through the taut cables to her anchors. This extra stress may have one of two results: if the ground-tackle is not heavy enough or strong enough either the anchors will drag or the cables will part; if, however, the ground-tackle is sufficiently strong and heavy the vessel may be dragged seaward little by little as each successive wave passes, until the cable is sufficiently slack for its bight to absorb the extra stress. When securing the vessel in a swell the cables of her ground-tackle must therefore be sufficiently slack, to absorb any extra stresses as the vessel rises and falls, but not too slack, otherwise the waves will slew her bows round. When refloating the vessel, however, these extra stresses can usefully be employed to haul her off, simply by keeping the cables as taut as possible.

When laying out ground-tackle, the anchors should be placed, if possible, in the best positions both for holding the vessel and for hauling her off.

If the available ground-tackle is insufficient for holding the vessel she should be scuttled, and sufficient compartments flooded to hold her steady. Scuttling a vessel will also prevent her from lifting and pounding in a heavy swell. The best method of scuttling is to burn holes with an oxy-acetylene burner in the ship's side above the turn of the bilge between frames and as close to the low water mark as possible. If oxy-acetylene plant is not available explosives may be used, but it must be borne in mind that any holes thus made will have to be patched and made good again before refloating, and so small charges only should be used. The selection of the compartments to be flooded in a merchant ship will necessarily depend on the nature and amount of cargo in the holds, and little guidance can be given in this respect; usually flooding two holds will be sufficient to keep a vessel steady, but more may have to be flooded if the weather is bad.

Use of Small Vessels or Craft for Dredging

When a vessel is aground on a soft bottom, sand or mud may silt up around her to such an extent that even when lightened she cannot be hauled off. In such a case the use of small craft for dredging away the silt by means of the wash from their propellers has proved very effective where the nature of the bottom is suitable.

Dredging by this means may be used for three different purposes: (i) to scour away the sea-bed under a stranded ship so that she can settle down deeper and so become waterborne, (ii) to dredge a channel seaward through which the

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ship can be moved to deeper water, and (iii) for tunnelling cavities under a beached ship to enable a diver to effect repairs. This type of dredging is effective where the bottom is of sand, soft mud, mud and sand, and shingle and stones, but is useless where the bottom is stiff clay. Disappointment may be experienced where the bottom consists of a layer of sand or silt one or two feet thick which is easily washed away but has hard, stiff clay or rock under it.

The most suitable type of vessel likely to be available for dredging would be a twin-screw tug drawing about 12 ft. 6 in. aft and 9 ft. forward, but a single-screw trawler or other similarly handy vessel will serve ; excellent results have been obtained with a landing-craft, infantry, as used for Combined Operations during the Second World War, but few of these craft are now (1954) available. The best results are produced when the propeller-stream strikes downward, and this can usually be effected by trimming the vessel well down by the stern.

Before starting dredging operations an accurate plan of the area around the vessel must be made and frequently checked as the work proceeds, otherwise the displaced silt may settle and bank up in inconvenient places ; dredging-craft have, in fact, been known to pen themselves in with banks of their own creation. Such banks are, however, more easily dispersed than the undisturbed sea-bed, particularly at full ebb or flood.

The depth at which dredging is effective depends upon the power of the dredging craft and the nature of the work ; for dredging a tunnel right under a vessel from one side to the other a powerful craft could not work effectively in a depth more than six feet greater than her normal draught, but when it is only desired to free mud from under the bilges of the vessel and not to extend the dredging as far as her keel, dredging has been effective in depths up to 26 feet.

As an example of the use which can be made of craft for dredging purposes let us take a ship lying evenly aground on slightly shelving sand and which cannot be moved by her own power, or with ground-tackle or by towing. Lightening her can still be tried, but as this would probably involve delay and the expense of obtaining a suitable ship for transhipment of cargo, dredging should first be attempted. Before starting operations the stranded ship is secured with efficient ground-tackle. Two dredging-craft are employed suitably trimmed by the stern and each moored for dredging with both bower anchors laid out with a good scope of cable and well spread. The craft then back into position, both the same side of the ship, one abreast the foremast and the other abreast the mainmast ; their sterns are then secured close to her side, using a strong hawser on the towing-hook which is taken right across the deck of the ship and made fast to a suitable point on the opposite side to obtain as much scope as possible ; if there is any sea a short towing-spring will have to be used and reasonable clearance from the ship be allowed. If there is not much current the foremost dredging-craft is secured at an angle of about seventy degrees to the fore-and-aft line of the ship, with her stern directed towards the bow of the ship, and the after craft is secured at the same angle to the fore-and-aft line but with her stern directed towards the ship's quarter.

Manila springs are led from each quarter of the dredging-craft through convenient leads to winches in the stranded ship so that the craft can be gradually hove along the ship's side as dredging progresses, and headropes are also run out for altering their angle of inclination. If the depth of water alongside the ship is such that the propeller of the dredging-craft is near the bottom,

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her stern can be held against the ship's side so that her propellers will be about eight feet clear, but in deeper water a greater clearance, say 12 feet, must be allowed and the trim of the dredging-craft by the stern must be increased as much as safety will permit.

The general object is to tunnel completely under the wreck if possible, and it is a gratifying moment when, perhaps after an hour or two of work, a sudden blow through of sand, mud, seaweed and dirt appearing in the water on the far side of the ship shows that this has been accomplished. With hawser and springs in position it is well to start slowly and adjust the strain on all parts ; too violent disturbance of the sand may cause choked condensers. The positions for the first effort might be chosen in way of the foremast and mainmast so that removal of the sand from underneath should not throw an undue strain on the hull. If the dredging-craft are held at too fine an angle, the flow of water will be deflected along the side and bilges of the ship instead of scouring in underneath her bottom. Once the silt is blown through to the other side, the stern of the dredging-craft should be gradually fleeted along to widen the cleared area without deepening it unduly and so perhaps straining the wreck. It is important to maintain the flow of water completely under the ship and not to allow it to be deflected so that the gap closes and a fresh start has to be made.

If it is impossible to tunnel completely under the ship the dredging-craft must be stationed one on each side of her, and must work persistently from amidships to the bow and from amidships to the stern, while keeping themselves at an angle of from 30 to 40 degrees to the ship, so drawing or sweeping the sand along. This will not only free the ship's bilges but will also scour the sand away on each side of her bottom, and so leave the ship resting throughout her length on a ridge of sand. The ship can then be freed by working her engines ahead with the rudder hard over first one way and then the other, and also by heaving in on either bow or quarter to haul her off the ridge. When thus dealt with a ship usually begins to swing a degree or so, this arc increasing gradually until she frees herself. As a rule the engines should not be driven astern, because this may bank up the sand around her and choke her condensers. Two dredging-craft are not essential, but they do accelerate the work. With a vessel aground by the head on a steep bank one dredger may be used on each bow. Sometimes one craft may be moored to do the actual dredging while the other is used to fan away and disperse the silt.

When dredging a channel through which to haul out a stranded ship it is usual to start at the deep-water end with the dredging-craft moored stern towards the ship and held in position by a dredging-hawser (say 3-in. F.S.W.R.) led from the ship. The dredging-hawser should, if possible, be made fast in the dredging-craft somewhere near her pivoting point, otherwise her stern will be girded and prevented from slewing. The strain is taken on the dredging-hawser and the engines of the dredging-craft are worked ahead, and as progress is made the cable of the dredging-craft is veered and the dredging-hawser hove in. If the dredger is kept on a dead straight course the channel would be only about 6 feet wide, so her stern is very slowly slewed from side to side by using her rudder, thus widening the channel and at the same time banking up the silt on each side. Frequent soundings are taken to check progress, and the course of the channel is well buoyed. On reaching the ship she is dredged free and swung into the channel in the manner already described.

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HAULING OFF A STRANDED VESSEL

When a ship is fast aground it is better to rely on strong and well laid out ground-tackle to haul her off than on tugs to tow her off.

The most powerful tugs can exert a pull of some 40 tons on a towing-hawser, but there are very few tugs of this power, and the average rescue tug can only exert a pull of from 12 to 15 tons. Far greater forces than these can be exerted by strong ground-tackle rigged with heavy purchases. Furthermore, in a swell, a tug cannot keep the towrope sufficiently taut to take advantage of any extra force obtainable as the vessel rises and falls on the waves, whereas with strong ground-tackle this extra force can be usefully employed to haul the vessel seaward.

Before laying out the ground-tackle it will be necessary to consider the best direction in which to heave the ship off, and whether she will refloat more readily bows or stern first. Broadly speaking, it is usually best to bring the vessel off bows first, because most ships are usually deeper in draught aft and so the bows can be more readily moved.

Usually the most difficult part of any heaving-off operation is to slew the vessel head or stern to the sea, but once this is done she can usually be refloated by perseverance and hard work. As soon as the vessel is end on to the sea the position is much improved, because she will be far less vulnerable to any subsequent bad weather, and by flooding-up and holding her securely by the ground-tackle it should be possible to weather any but the worst of storms. Ships which have been driven ashore when lightly laden can often be assisted by gales once the preliminary work has been completed, because a heavy swell running in on a beach will help to lift her, and as she lifts a very great stress will be brought on the ground-tackle and so cause the vessel to surge seaward with each lift. In such cases it is most important to keep a heavy strain on the ground-tackle, otherwise the seas will tend to swing the ship broadside on to the beach again instead of working her slowly seaward.

Ground-tackle is therefore usually rigged with strong purchases so that it can be subjected to heavy stresses and kept as taut as possible. Rigging these purchases leaves much scope for improvisation, because usually only salvage vessels and bases have all the necessary gear. It must be borne in mind that very considerable stresses are set up during these operations, and that the normal deck-fittings are not sufficiently robust to use as anchorages for the standing blocks of purchases, or for the stoppers used when fleeting the purchases.

In order to illustrate some of the methods used to refloat a stranded vessel, descriptions of actual incidents are given in the following pages. These have been selected because it is considered that they are normal refloating operations without any great complications, and of the kind likely to be encountered by seamen.

Three Examples of Salving Stranded Vessels

HEAVING OFF A SHIP HARD AGROUND ON A TIDELESS SANDY BEACH (Figs. 43–45).

This case was that of a merchant ship of 5,780 tons gross, 449 feet in length and of 58 feet beam. The ship was driven ashore in bad weather on to a firm, sandy beach with isolated patches of submerged rock. She was lightly laden, having only water-ballast in the double-bottoms and 300 tons of shingle in No. 5 hold. On first grounding the vessel pounded on the beach, the heel of

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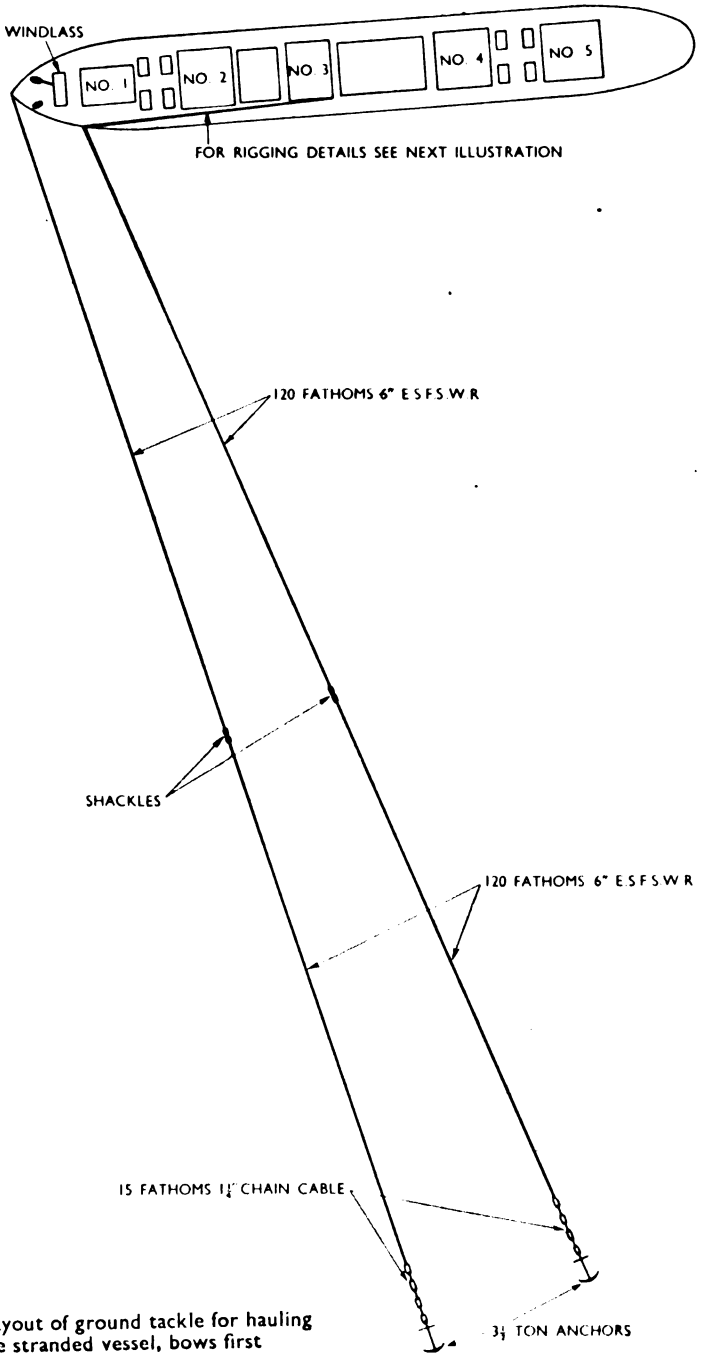

Fig. 43. Layout of ground tackle for hauling off the stranded vessel, bows first

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her stern-frame was fractured, and she was holed in No. 4 double-bottom tank and in the port bilge of No. 4 hold, which hold flooded to water-level. A rescue tug managed to pass a towrope across to the ship while the gale was still blowing, but the weight of the water in her after end and the force of the seas striking her broadside prevented refloating her, though the tug's efforts probably prevented her bow from being driven further ashore.

As soon as the weather moderated, an inspection was made and it was found that the vessel was hard aground along her entire length ; there was just sufficient water under the bows to refloat her but she was 2 ft. 6 in. short of her floating draught on grounding at the after end. There was no obstruction to prevent her from being hauled off bows first, so ground-tackle was laid out for this purpose. No anchors were laid out to hold her stern because it was considered that the weight of water in No. 4 hold would be sufficient to prevent her after end from driving further ashore in any subsequent bad weather. The tidal range was only a few inches, so no assistance could be expected from the rise.

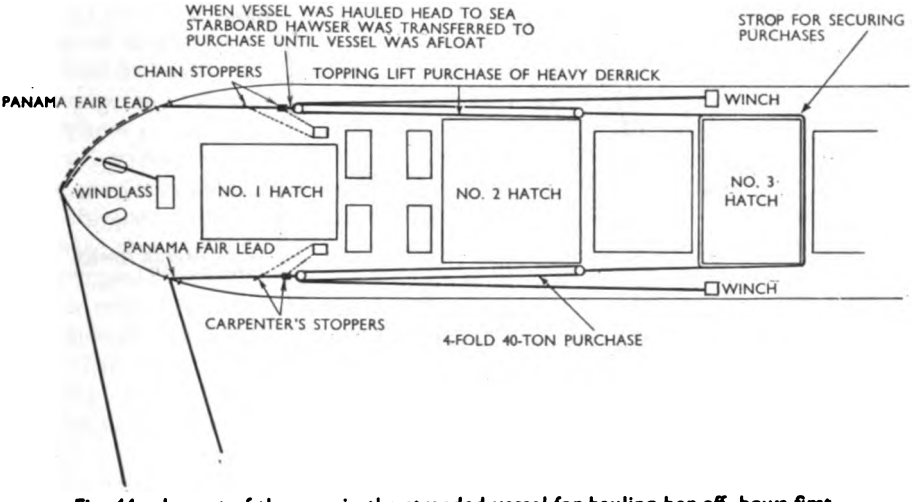

Fig. 44. Layout of the gear in the stranded vessel for hauling her off, bows first

A 3½-ton anchor with 15 fms. of 1¼-in. chain cable shackled to two 120-fm. 6-in. E.S.F.S.W. hawsers was laid out to provide the main anchorage for the heaving-off gear (see Fig. 43). The end of the hawser was brought in through a Panama fairlead forward on the main deck and connected by a Carpenter's stopper to a four-fold, 40-ton purchase rove with a 2½-in. E.S.F.S.W.R. fall which was taken to a 5-ton winch abreast No. 3 hatch. This purchase was anchored by a strop made of several turns of 3½-in E.S.F.S.W.R. around the coaming of No. 3 hatch and the forward Samson-post at No. 3 hold. An additional stopper to hold the hawser while overhauling the purchase was secured around the base of the winches at the after end of No. 1 hatch (see Fig. 44).

Another 3½-ton anchor, with similar lengths and sizes of chain-cable and wire hawser was laid out and the end of the hawser was brought round the bows and up through the starboard hawsepipe to the windlass on the forecastle-head (see Fig. 43). The purpose of this second anchor was to provide a means of hauling

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SHORE

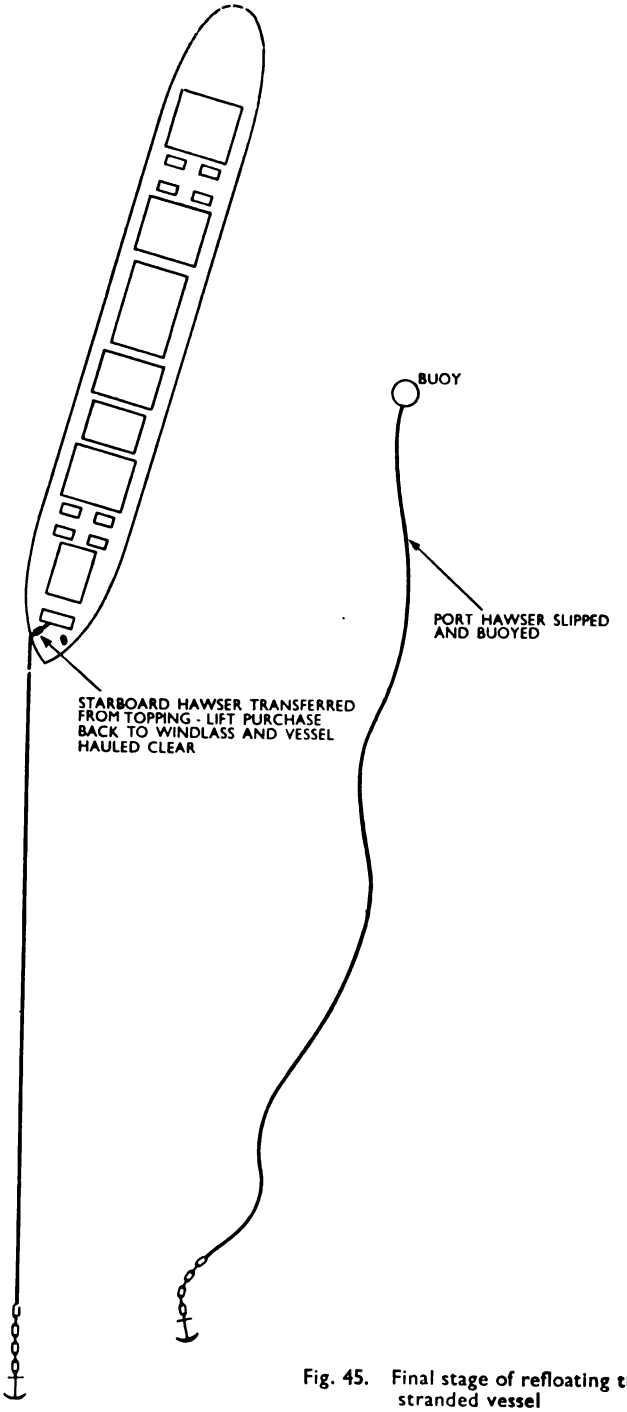
BUOY
PORT HAWSER SLIPPED AND BUOYED
STARBOARD HAWSER TRANSFERRED FROM TOPPING - LIFT PURCHASE BACK TO WINDLASS AND VESSEL HAULED CLEAR

Fig. 45. Final stage of refloating the stranded vessel

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the ship clear of the beach quickly when she refloated and so prevent her from sustaining further damage by pounding. It was expected that the vessel would have to be refloated under adverse conditions because there were no facilities for the discharge of the ballast, and even if her ballast were discharged she would still be short of water to refloat.

A portable salvage pump of 120 tons-per-hour capacity was placed on board and rigged in No. 4 hold, and this, with the ship's bilge-pump, proved sufficient to overcome the leakage. When all was ready No. 4 hold and all ballast-tanks which could be pumped out were emptied, and a heavy strain set up on the anchor-hawsers, these being hove in slowly until all the gear was " bar-taut." After the strain had been kept up for six hours the vessel's bow was hove round, and once it started to move the slack came in quite well until the ship was heading out to sea. No further movement was obtainable and there was now 8 inches of water under the stem, but still 2 ft. 6 in. less than the floating draught under the stern.

The heavy strain on the ground-tackle was maintained constantly for the next three days without result. During this period the leaks in No. 4 hold were reduced by plugging them with wooden wedges, etc., but no attempt was made to effect more permanent repairs as it was considered advisable to retain some means of flooding-up should the weather deteriorate.

The 6-in. hawser from the second anchor was then unrove from the starboard hawespipe and led in through the foremost Panama fair lead on the starboard side where it was connected to a topping-lift purchase off one of the ship's heavy derricks, rigged in a similar manner to the 40-ton purchase, thus obtaining a greater heaving-power than that provided by the windlass. No Carpenter's stoppers were available for this second set of gear and consequently the purchase was attached by means of a heavy chain-stopper, a similar stopper being rigged for use when overhauling the purchase (see Fig. 44).

The next day the weather was bad, with heavy seas running in on the beach. The wedges were knocked out of the leaks in No. 4 hold and all ballast-tanks which had been pumped out were flooded-up. No attempt was made to heave the ship off but any slack which became apparent in the gear was taken up and the hawsers were constantly attended to prevent undue chafing in the fair-leads.

The weather remained unsuitable for the next two days, but then the wind began to drop and the sea moderated. As soon as the sea had abated sufficiently the ship was again lightened and heaving-in was resumed. As the bows of the ship lifted in the swell heavy stresses were brought on to the gear and gradually, inch by inch, the vessel began to work to seaward. Some twelve hours later the slack began to come in quite well, indicating that the vessel was nearly afloat. The starboard purchase was then disconnected and the starboard hawser brought back through the hawsepipe to the drum of the windlass while heaving on the port hawser was continued. Shortly afterwards the stern became free and the ship was hove clear by the windlass and the starboard anchor-hawser. The purchase was disconnected from the port hawser, which was slipped and buoyed (see Fig. 45), and tugs were sent for to tow the ship to a nearby port. While waiting for the tugs the ballast-tanks were flooded-up, and the leaks in the bilge of No. 4 hold were stopped by means of wedges and plugs. A drain was left from the affected bilge-pockets, which were then filled with concrete, and when this had set the limber holes were plugged. The vessel was then towed to the repair port without any further repairs being required.

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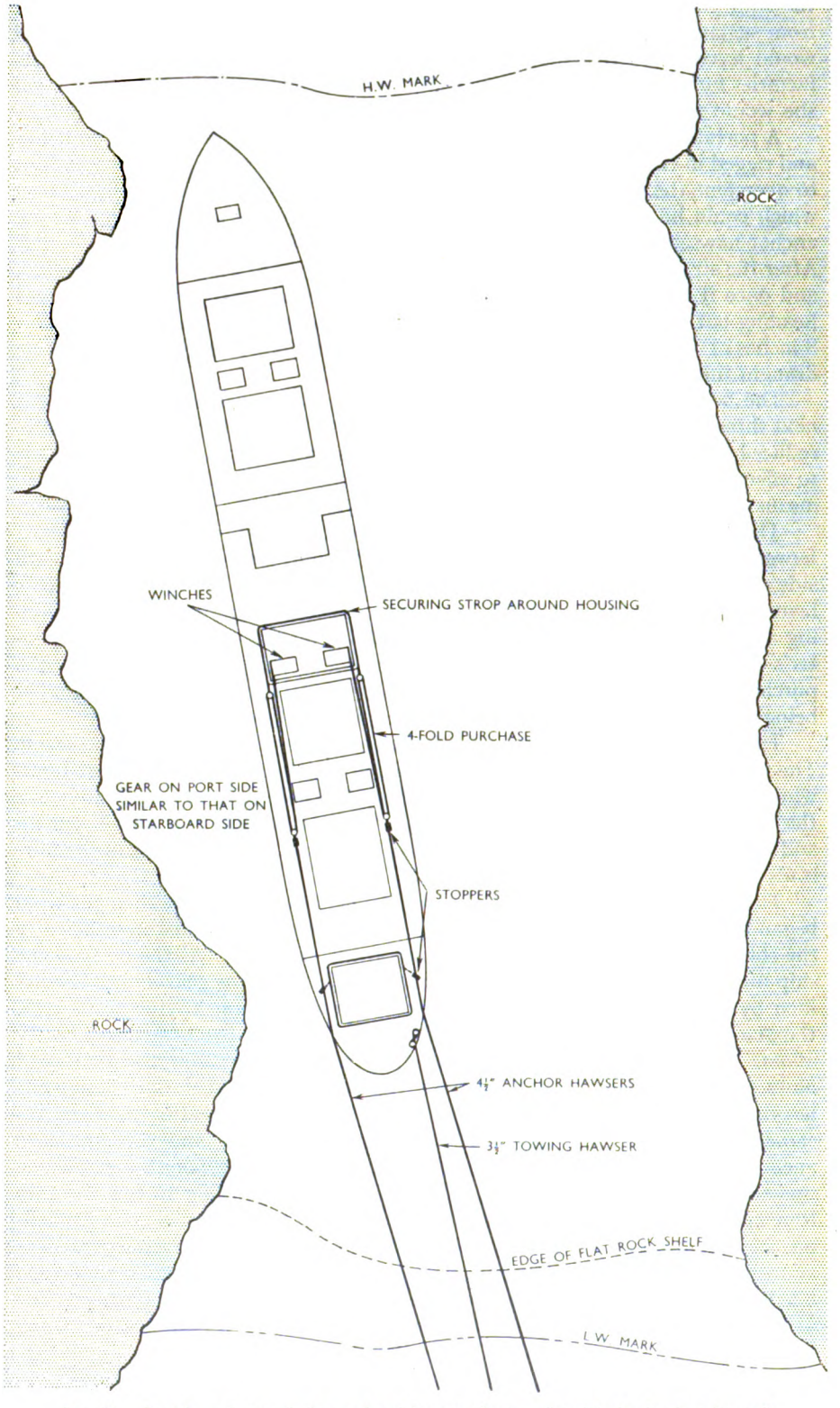

Fig. 46. Position of stranded vessel and layout of ground tackle for hauling her off

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SALVAGE OF A VESSEL DRIVEN ASHORE BETWEEN TWO ROCKY LEDGES.

A merchant ship of 2,883 tons gross, 315 feet in length and of 46 feet beam, proceeding in ballast during exceptionally heavy weather, found it impossible to keep off a lee shore. Visibility was bad but the master selected a place where there was a break in the heavy surf and ran his ship ashore, hoping that she would find a quieter resting place than appeared likely if she were driven ashore as the wind and sea dictated. The crew were successfully landed by breeches-buoy and the vessel was left until the weather moderated. A few days later a small salvage party boarded the ship, which was found to be lying in a small cove on a flat shelf of rock between two outlying reefs (see Fig. 46). The port side aft was against one of the reefs, which had prevented her from swinging broadside on to the sea, so the ship was still lying stern to sea, having swung only a few degrees since she was run ashore. At high water the fore part of the ship was afloat, only the stern being hard aground. Had it been possible to swing the ship through 16 points bow to sea she could have been trimmed bow down and easily refloated ; but the high rocks on each side made this impossible, and it was evident that she would have to be refloated stern first, a much more difficult operation because there was 1 ft. 6 in. less water aft than this required. At low water the vessel dried out almost for her entire length and a survey revealed that there was heavy damage throughout her bottom and that her rudder-post and rudder had carried away and were lying close alongside under the starboard quarter. The after peak, all double-bottom ballast-tanks and the shaft-tunnel were open to the sea, and it was evident that no repairs to recover buoyancy in these compartments could be carried out. Apart from minor leakage from the shaft-tunnel into the after holds the rest of the ship was dry. By using salt water in the boilers it was possible to provide steam for working the winches.

The holding ground offshore was known to be poor so arrangements were made to lay out the anchors for hauling the ship off with a good scope on their cables. The services of a shallow-draught coastal vessel were obtained and 360 fathoms of 4½-in. wire hawser were flaked down on her deck. In fine weather this coaster approached as close to the stern of the ship as possible and passed the end of the hawser on board the port quarter by means of a messenger ; the coaster was then backed out seaward as she payed out the hawser, taking care to keep it taut. To the end of this hawser a 3½-ton anchor was shackled, and this was backed up by another 3½-ton anchor secured to the first anchor by a length of chain-cable. A similar arrangement of ground-tackle was laid out on the starboard quarter of the wreck and purchases rigged in the manner described below were connected to the hawsers of each set of anchors. A rescue tug was also available and so an additional 360 fathoms of 3½-in. wire rope was laid out and buoyed-off to serve as a towrope.

The ship was a well-deck ship of the " three-island " type with cargo winches abaft the accommodation housing amidships above the main deck, and these were used for hauling on the purchases. Two four-fold purchases, rove with 2½-in. wire falls, were rigged above the after well-deck, one on each side, from the after end of the midship housing to the fore end of the poop deck. Their standing blocks were anchored by a strop made of strong wire rope which was passed right round the midship housing, wooden chafing blocks being placed as necessary to prevent the strop from chafing on the sharp corners.

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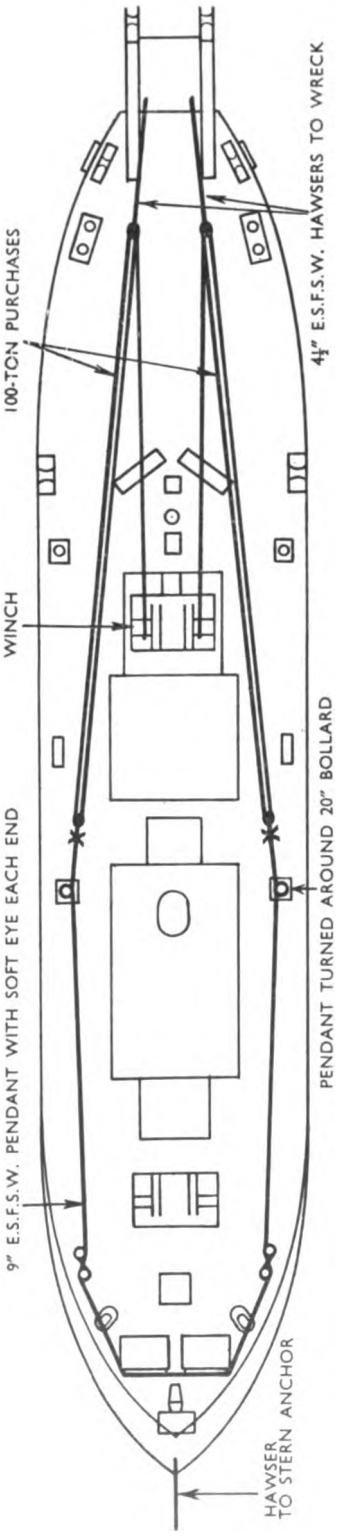
100-TON PURCHASES
4½" E.S.F.S.W. HAWSERS TO WRECK
WINCH
9" E.S.F.S.W. PENDANT WITH SOFT EYE EACH END
PENDANT TURNED AROUND 20" BOLLARD
HAWSER TO STERN ANCHOR

Fig. 47. Layout of gear on board the boom-defence vessel for hauling off the stranded ship

Their moving blocks were attached to the 4½-in. anchor-hawsers by means of Carpenter's stoppers, and two additional Carpenter's stoppers were provided on the poop, anchored by several turns of 3½-in. wire rope around the poop housing to hold the anchor-hawsers while overhauling the purchases. The position was then as illustrated in Fig. 46, and the advent of spring tides to assist the operations was awaited.

Consideration was given to the provision of extra pumps should further damage ensue during refloating. No small portable pumps similar to the 70-ton electric and diesel pumps used in the Royal Navy were available, only large petrol-driven salvage-pumps could be obtained in the vicinity, and their transport to the site presented some difficulty. Finally, however, as it was considered to be essential to have them, it was decided to ferry them by motor-launch from a vessel offshore. This was successfully accomplished and the pumps were hoisted on board by the ship's own derricks, and rigged in her forward and after holds. All was now ready for an attempt to refloat the ship.

As soon as the tides served, heaving in was started and continued from well before, until well after, high water. The rescue tug picked up the towrope provided and every effort was made to move the ship's stern to sea. A few feet of hawser were gained during the first attempt but it was impossible to tell whether this resulted from the anchors dragging or whether, in fact, the ship had moved. At low water, however, an inspection of the stern from the rocks showed that the ship had moved some eight or ten feet in the required direction and that the rock on which she was resting was cracking and breaking up under the strain. To assist the disintegration of this rock, wire hawsers were run from each bow of the ship to other rocks inshore to enable the ship to be slewed on her heel during the high-water period when she was afloat forward.

Further heaving was carried out during the next high water, and an inspection at the subsequent low water revealed steady progress in the desired direction. The depth of water at the stern had now been increased by some

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nine inches and it was confidently expected that the operations would be successful before the spring tides began to fall away. Again, at half-tide on the next tide, the work was resumed and the anchor hawsers were steadily hove in by inches. At approximately half an hour after high water the remaining ledge of the shelf of rock gave way and the vessel slid seaward and was towed between the reefs into deep water. The slewing hawsers at the bows and also the port anchor-hawser were slipped. The starboard anchor-hawser fell slack when the ship moved seaward and then fouled some rocky outcrop on the bottom and brought up, leading shoreward. The stopper was jammed shut and could not be released, so the fall of the purchase had to be slipped and allowed to unreeve. The anchor-hawser then went by the board with a run complete with the moving block of the purchase, causing some confusion on deck, but fortunately no damage or casualties. The towrope was then transferred to the bow and the vessel successfully towed to the nearest port, where she was handed over to the repairers for docking.

In both the foregoing examples of salving stranded vessels, which may be taken as being typical of such operations, success depended on the ability of the stranded vessel to supply steam. In similar instances where no steam was available a vessel has been salved just as well by operating her winches by compressed air supplied by portable compressors placed on board; and in extreme cases, where no power was available, the vessel has been hauled off by rigging additional purchases luff-upon-luff and using manpower only. This latter course, although proved possible with ships of up to 5,000 tons gross, is not recommended because it involves extremely trying and exhausting work for large numbers of men, but it should never be ignored as a last resort. The average ship's winch will function fairly efficiently on compressed air, but attention must be paid to oiling the cylinders, and for this purpose a light engine-oil should be used.

Salvage of a Ship which was Silted-up and without Power

This example differs from the other two in that dredging was used to free the ship from silt which had banked up round her, and another vessel moored offshore was used to haul her off because there was no power in the stranded vessel to work her windlass and her winches. A boom-defence vessel of the "Bar" class was used for hauling off, and the suitability of this type of vessel for work of this kind should be remembered because they are available in most naval bases throughout the world. Any other type of vessel can, however, be used equally well for hauling-off purposes provided that she is equipped with winches, that she has sufficient deck space for working the necessary purchases, and that anchorages of sufficient strength to hold the purchases can be devised.

The stranded ship, a vessel of some 1,800 tons gross, had been washed high up on a soft, sandy beach in bad weather, and a sandbank about four to six feet high had formed on her seaward side. The tidal range was only 14 inches, and at high water the depth on the inshore side was two feet less than that required to refloat the ship. The ship was fully laden, but even if totally discharged she would still not have been able to ride over the bank formed on her seaward side. Furthermore lighters for discharge were not available and the value of the cargo precluded any suggestion of jettisoning.

The boom-defence vessel was moored by means of her heavy stern-anchor at the full scope of its cable, and two 4½-in. E.S.F.S.W. hawsers, each 120 fathoms long, were passed from her to the ship. The end of each hawser was

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connected in the boom-defence vessel to a 100-ton purchase rigged as shown in Fig. 47, and the other end was secured in the ship by reeving it, twice, up through one hawsepipe and down through the other, and then shackling it to its own bight. Heaving in alone was attempted during a brief period of suitable sea conditions with a fairly heavy swell, but without result, so it was decided to attempt dredging by the propeller-stream of another craft.

A small diesel harbour-tug was employed as a dredger, and as much pig-iron ballast as could safely be carried was placed on her after deck. A suitable anchor shackled to a length of 3½-in. E.S.F.S.W.R. was laid out to moor the tug, because her cable was not long enough for this purpose. Another 3½-in. wire hawser, led from the towing-hook, was used to secure the tug to the ship, and warping-hawsers were provided from each quarter to fleet the stern of the tug to the required position. The tug was able to back in to within some 20 feet of the ship and was moored approximately amidships at an angle of 30 to 40 degrees to the latter's fore-and-aft line, her own stern being directed towards the bows of the ship. It was not intended to attempt to dredge right under the ship but merely to disperse the bank of sand which had been formed and free the ship's bilge sufficiently to enable her to be swung free by heaving in from the boom-defence vessel. Dredging was started and the stern of the tug was worked from amidships to the bows of the ship to fan the dredgings around her stem clear of the arc through which she was expected to swing. With each fleet the tug dredged some three to four feet off the bank, and she was progressively hove astern until she was working close alongside the ship. Dredging was continued until the sand was scoured away for some six or seven feet under the ship's bottom. It was found necessary at frequent intervals to transfer the tug to a position off the ship's bows to clear away banked sand, because silt tended to be deflected from the ship's side and settle some 12 feet seaward of her bows.

After some 16 hours of continuous work the whole of the seaward side of the ship, from amidships to her bows, was cleared to a depth of some four feet below her bottom. The tug was then repositioned to work from amidships to the stern in the same manner, and equally successful results were obtained.

A similar tendency for the silt to bank up on the seaward quarter of the ship was encountered, but it was found that this banking could be rapidly dispersed around the ship's stern by placing the tug in a suitable position. After about 12 hours of constant work on the after end a change of three degrees in the direction of the ship's bows was reported and the boom-defence vessel reported having gained some slack in the towing-hawsers. These efforts were persistently continued and the ship was slewed gradually until she was lying head to sea. The ship was now afloat for two-thirds of her length from her bows aft, but her after end was still hard aground. The weather was calm with no sea to assist refloating, so dredging was continued. The anchor of the tug was relaid to enable her to place herself at an angle of 20 degrees to the fore-and-aft line of the ship with her stern secured against the quarter of the ship. The engines of the tug were again started and kept going for the next six hours, until a blow of sand was reported from the opposite side. Simultaneously the ship began to move slowly seaward, and a few moments later she was well afloat. The tug was slipped and left to recover her anchor, while the ship was hove clear by the boom-defence vessel for towing away to the nearest harbour for discharge and repair.

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Remarks on Equipment, Vessels and Plant required for Major Salvage Operations

The examples given in the preceding pages described the successful salvage of stranded ships for which little specialised equipment was required. From a general knowledge point of view, however, it is considered that a brief description of some of the methods used to raise sunken ships and of the special craft and equipment necessary for such major operations will be of interest and value to the seaman.

Cofferdams

When a vessel is sunk in shallow, sheltered water the usual method of raising her is to seal all except certain selected openings, effect repairs to the damage, and then build watertight, tower-like structures, called "cofferdams," over the selected openings so that they extend from the hull of the ship to well above the surface of the sea. The necessary pumps can then be lowered down the cofferdams and installed inside them on the deck of the ship, and the ship is then raised by pumping her clear of water.

With merchant vessels the cofferdams are usually built up on the hatch-coamings of the cargo-holds, and timber is generally used in their construction because it is more easily handled by divers than steel. The cofferdam is built up on the coaming, plank by plank, and secured to upright supports fitted all round. The whole structure is then well braced and shored on the inside to enable it to withstand the external water-pressure.

For success this method needs sheltered water, because cofferdams which can be erected by divers are not very robust and will not stand up to any heavy sea. The depth of water from which a ship can be raised in this manner is limited by the strength of her decks, because they must withstand a considerable pressure when pumping begins.

Pontoons and Lifting-craft

Where insufficient buoyancy is obtainable by pumping alone, pontoons or special lifting-craft are used.

The Admiralty salvage pontoon consists of a horizontal steel cylinder divided into watertight compartments which can be flooded and then emptied by compressed air, and it is fitted at one third of its length from each end with a vertical mooring-pipe which extends through it from top to bottom. For lifting work the pontoons are usually used in pairs, and the lifting-capacity of each pair is about 160 tons.

Having decided on the number of pontoons required to raise the vessel, an equivalent number of heavy lifting-hawsers are passed in pairs beneath her, spaced at suitable intervals along her length, and the ends of each pair are then rove through the mooring-pipes of the corresponding pair of pontoons. The pontoons are then flooded up and sunk, and the lifting-hawsers are hove taut and secured by divers on top of the pontoons by means of special clamps resembling Carpenter's stoppers. When all is ready the buoyancy-chambers of the pontoons are blown clear of water by compressed air, and the vessel is raised by the lift exerted by the now buoyant pontoons.

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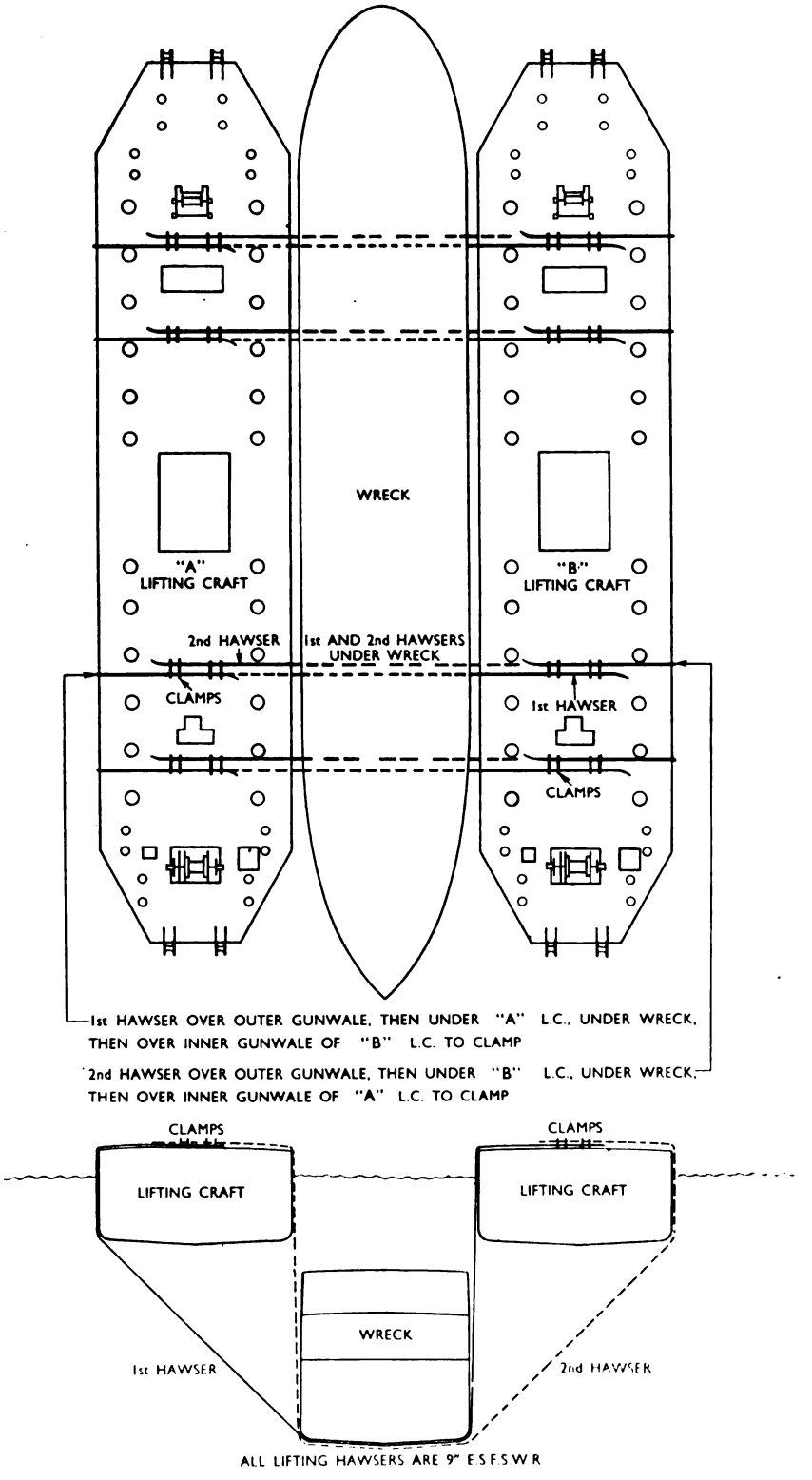

Fig. 48. Method of placing lifting-craft to raise a sunken wreck

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Pontoons are also used, secured firmly to the side of a vessel while she is being salvaged, to give her stability or to prevent her capsizing.

The principle on which lifting-craft operate is the same as that of pontoons, but they rely mainly on the rise of the tide for their lift and are not submersible ; they can, however, be flooded down to a deeper draught by water-ballast which is subsequently discharged during the lifting operations, thus increasing the lifting range by a few feet. There are three types of Admiralty lifting-craft in service, viz : 600-ton, 750-ton and 1,100-ton. They normally work in pairs, the wreck being slung between them on special 9-in. E.S.F.S.W. hawsers rove as shown in Fig. 48 ; this is almost invariably the method employed for lifting sunken submarines.

The two lifting-craft are first securely moored head and stern abreast each other over the sunken ship, and about the breadth of the sunken ship apart from each other. Wire-rope messengers are then passed under the sunken ship at positions to suit the pinning points on the lifting-craft. The lifting-hawsers are then passed in pairs, one leading from the inner side of the first lifting-craft to the outer side of the second, and the other leading from the outer side of the first lifting-craft to the inner side of the second. The opposite ends of each pair of hawsers are then led across the deck of each lifting-craft and clamped to each other by specially constructed clamps. At low water the pumping out of the ballast is begun and as the lifting-craft rise the hawsers are allowed to render a little in their clamps until they are all bearing an even strain; the clamps are then hardened down so that the vessel is lifted evenly on the rising tide. At high water the moorings of the lifting-craft are slipped and the whole unit is towed inshore until the ship again grounds. Weather permitting, this procedure is repeated on each subsequent tide until the vessel reaches a beach or bank where she can be patched and made sufficiently seaworthy to be towed to the nearest dock.

Vessels which have completely capsized are sometimes floated upside down by means of compressed air, but generally a ship so raised cannot be righted, and is only fit for sale to ship breakers. A vessel lying on her side can be righted by sealing and controlled pumping, water being left in selected compartments on the high side and buoyancy employed on the low side as the righting-moment. Alternatively, she can be parbuckled upright by means of strong hawsers which are usually secured to levers built up on the ship's side, and then hauled on by means of purchases anchored to fixed points ashore. If the vessel is large a combination of the two methods is used, and salvage pontoons may also be secured to the low side to provide additional righting-moment with their buoyancy.

Salvage Plant

Stocks of the necessary plant and equipment for salvage operations are maintained ready for service at most naval dockyards, and these consist of portable pumps, air-compressors, electric generators, cutting and welding equipment, diving equipment, hawsers, blocks and many other items.

The sizes, types and capacities of the portable salvage-pumps provided in the Royal Navy are given in the following table.

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SIZE	TYPE	CAPACITY IN TONS PER HOUR	COMBINED HEAD* IN FEET
12-inch	Motor-driven	750	40
8-inch	Motor-driven	400	40
6-inch	Motor-driven	200	40
4-inch	Motor-driven	120	40
3-inch	Motor-driven	30	40
8-inch	Centrifugal, steam-driven ...	350	40
6-inch	Duplex, steam-driven	75	40
3-inch	Duplex, steam-driven	25	60
2½-inch	Submersible sump, air-driven	31	†40 (actual)

*The " combined head " of a pump is the sum of : (*a*) the height of the pump above ts lowest suction-point, and (*b*) the greatest height above the pump reached by its discharge-pipe.

† The " actual head " of a pump is the height above the pump of its discharge-point, less an allowance for frictional and other losses.

Of these pumps the 3-in. motor-pump is the only one which is not a true salvage-pump, and although it is handy for small compartments and for transferring water it should never be relied upon to keep the ship afloat. All the pumps mentioned are constructed to be easily transportable, and are supplied with slings. Each pump has supplied with it the necessary suction- and discharge-pipes, spares, tools and gear, and an initial supply of consumable stores. Most of these items are contained in a spare-gear box which is also easily transportable. Steam-pumps are the most reliable for use on salvage work, but have the disadvantage of the difficulties often experienced in obtaining the necessary steam to drive them ; 6-in. and 3-in. steam-pumps function satisfactorily when driven by compressed air. Motor-pumps are handy in that only supplies of fuel and oil are required, but they have the disadvantage of being more liable to breakdown, although improvements in the design of internal combustion engines of recent years have added considerably to their reliability.

Portable air-compressors are supplied complete with air-driven tools which function under water and are used by divers; they consist of hammers, drills, wood-borers, rock-drills, etc.

Underwater cutting equipment, both oxy-hydrogen and oxy-electric, also oxy-electric underwater welding gear and above water burning and welding gear, are maintained together with supplies of gas and the necessary electric generators.

Salvage Vessels

There are two types of Admiralty salvage vessel in service, the " Ocean " class and the " Coastal " class. The " Ocean " class are vessels of about 1,680 tons displacement, twin-screw, of shallow draft and specially strengthened to allow them to be grounded. They are designed for offshore salvage operations under adverse weather conditions and are fitted for fire-fighting. They have a maximum speed of 12 knots and an endurance of 4,500 miles at their econo-

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mical speed of eight knots. In addition to the ship's normal auxiliaries, a 14-in. salvage-pump, an air-compressor and a fire-pump are fitted in the engine-room. The salvage-pump has an output of 1,000 tons per hour at a combined head of 40 feet. Fixed suction-pipes lead forward and aft to manifolds on deck, and each manifold is fitted with six 6-in. flexible suction-pipes which are passed into the ship being salvaged. The pump is fitted with a sea-suction and can be used for flooding-back if required.

The air-compressor has an output of 340 cu. ft. of free air per minute at a pressure of 100 lb. per sq. inch. An air main runs fore and aft below the upper deck from the air reservoir to valves and connections throughout the ship above and below decks. Full sets of air-driven tools and equipment are provided, and suitable manifolds on deck for supplying air to the wreck are fitted.

The fire-fighting equipment includes two 4-in. " monitors " situated abaft the funnel on the upper deck, three 2½-in. hose-manifolds each with six connections, 16 ordinary branch-pipes, two monitor-type branch-pipes and ten foam-making branch-pipes, 16 variable-spray nozzles, and 24 one-inch nozzles. Foam compound is stored in a 1,000-gallon tank in the engine-room. In addition, 45 cylinders of liquid CO_2 with a full range of hoses, adaptors, manifolds, etc., are included together with three portable units, each of two cylinders, mounted on trolleys.

The ships are provided with a well-equipped workshop and large quantities of portable salvage equipment with the necessary stores. Extra-heavy anchors and cables are carried, and powerful capstans with heavy deck-clench plates and fittings are provided to enable the ships to haul off stranded vessels. In fact they are virtually fully equipped and mobile salvage bases.

" Coastal " class salvage vessels are single-screw ships, specially designed and primarily intended for harbour clearance and shallow-water salvage work. They are heavily built to take the ground and can steam with a great load slung from their bows. Their approximate displacement is 1,068 tons, with a speed of nine knots, and an operating radius of nearly 2,000 miles under normal conditions, but this can be increased to 3,500 miles by carrying additional fuel in reserve bunkers. In common with the " Ocean " class they are fitted for fire-fighting, but not on such a lavish scale. Twin lifting-horns which overhang the stem are each capable of a lift of up to 50 tons, and lifts of up to 200 tons can be taken over the bows by means of two six-fold purchases rigged on the fore deck. Heavy deck-bollards are fitted, and side-lifts can also be taken. These vessels are also fitted with a workshop and carry a good outfit of salvage equipment and stores.

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CHAPTER X

Wreck Dispersal

A SHIP which is sunk in a fairway or in frequented waters is dangerous to shipping if there is insufficient water over the wreck at all states of the tide. It may be impracticable or inexpedient, however, to salvage such ships, in which case they must be disposed of as quickly as possible by some other means. This is best done by "digging a grave" alongside the wreck with explosive charges, into which the wreck falls and is then buried by the scouring action of the tidal stream on the bottom, or by blowing up the whole or part of the wreck with explosive charges. Wrecks lying in less than 45 ft. of water at mean low water springs must be blown up or buried as nearly as possible to the level of the bottom, and wrecks lying at greater depths must be reduced until there is a clear depth of 45 ft. above them at mean low water springs.

When the wreck has been located its position must be marked, and the wreck and its surroundings carefully surveyed. The best method of dealing with the wreck is then decided, and the dispersal plan drawn up. The required charges are then laid and exploded in accordance with the plan, and finally the position is again surveyed to ensure that there is now a sufficient depth of water over it. As no two wrecks are the same and they are never sunk in quite the same way, it is not possible to forecast how long any particular dispersal operation will take or how much equipment it will require; the operation may take only a few days or it may take several months, but a wreck dispersal vessel should usually be able to average at least one wreck a month.

A wreck dispersal vessel should be equipped with some navigational aid such as "Decca" or "Loran"; also asdics and echo-sounding gear. She should carry two seaworthy motorboats fitted for echo-sounding and sweeping; also Dan buoys, floats, and pellets, with their moorings; special "drift sweeps"; and a sufficient number of depth-charges. It is also a good plan to mark off her gunwales or decks in fathoms and feet to facilitate measuring and cutting ropes to the required lengths.

Divers are not normally employed in wreck dispersal operations because they can only work in calm weather and at slack water, and it would be uneconomical to wait for such suitable conditions. Their work is also liable to be delayed if mine-sweeping or other operations using explosives are taking place within a radius of five miles. Divers have been found necessary only in isolated cases, such as when a boiler could only be destroyed by placing a charge inside it.

The following terms are commonly used in wreck dispersal:—

A blow	the simultaneous explosion of a number of charges in or around the wreck.
A peak	an isolated projecting feature of a wreck, such as a mast or funnel, or the highest point of a wreck above the bottom.
A scour	a crater or depression made in the bottom, either by explosives or the scouring action of the tide.

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Marker	... ...	a buoy, float, or pellets, laid to mark the area of the wreck or one of its features.
Span	... ...	the length of wire rope stretched between charges which is designed to foul the wreck or one of its features as the charges are laid.

Locating a Wreck

When the position of a sunken wreck which is out of sight of landmarks has been fixed and charted, but not buoyed, a navigational aid such as Decca or Loran is most useful for bringing wreck dispersal craft to the charted position, the exact location of the wreck being then determined by asdics or sweeping. If the wreck has been buoyed and the bearing of the wreck from the buoy is known, the initial approach should be made on this bearing, but if the wreck is not immediately found the buoy should be disregarded and a systematic search begun. Some wreck-buoys have been found to be as much as four cables out of position.

As soon as an echo indicating the position of the wreck has been obtained it should be marked by two buoys, one on each side of it. In favourable weather this is done by lowering a boat and directing her towards the wreck until she can obtain echo-soundings of it; but in unfavourable conditions the buoys must be laid by the vessel while she is in asdic contact with it.

Small wrecks, or those well silted up, may not give an asdic echo, and in such cases a square centred on the wreck's charted position must be marked out and then swept by the vessel. A drift sweep is used if there is sufficient depth of water over the wreck, or, if the wreck is in very shallow water, the sweep must be carried out by boats using echo-sounding.

The position of a wreck in shallow water may sometimes be indicated by breaking waves, or in tidal waters by a tide-rip or eddies on the surface directly over the wreck.

Marking a Wreck

If no wreck-buoy has been laid, a Dan buoy with a red or a green flag should be laid as an indication to shipping to keep well clear of the position.

Markers should then be laid to indicate the exact position of the wreck and the direction in which it is lying, and to provide suitable marks for the boat which is laying the charges to enable her to determine her exact position in relation to the wreck.

The number of markers required and the position in which to lay them depend on the size of the wreck and the direction in which it is lying in relation to the tidal stream. Usual practice is to lay one marker at each end of the wreck, two or more athwart the stream, both upstream and downstream of the wreck, and one or more on each side of the wreck, so that it is enclosed roughly by a rectangle of markers (see Fig. 49). All markers should be laid about 40 yards from the wreck to ensure that they are not carried away or sunk by " blows."

The usual markers consist of an Oropesa float, or three or four pellets, with a mooring rope about 20 ft. longer than the depth at high water shackled to a $\frac{1}{2}$-cwt. sinker. In strong tidal streams a $1\frac{3}{4}$-cwt. sinker or a 50- to 60-lb. boat's anchor should be used.

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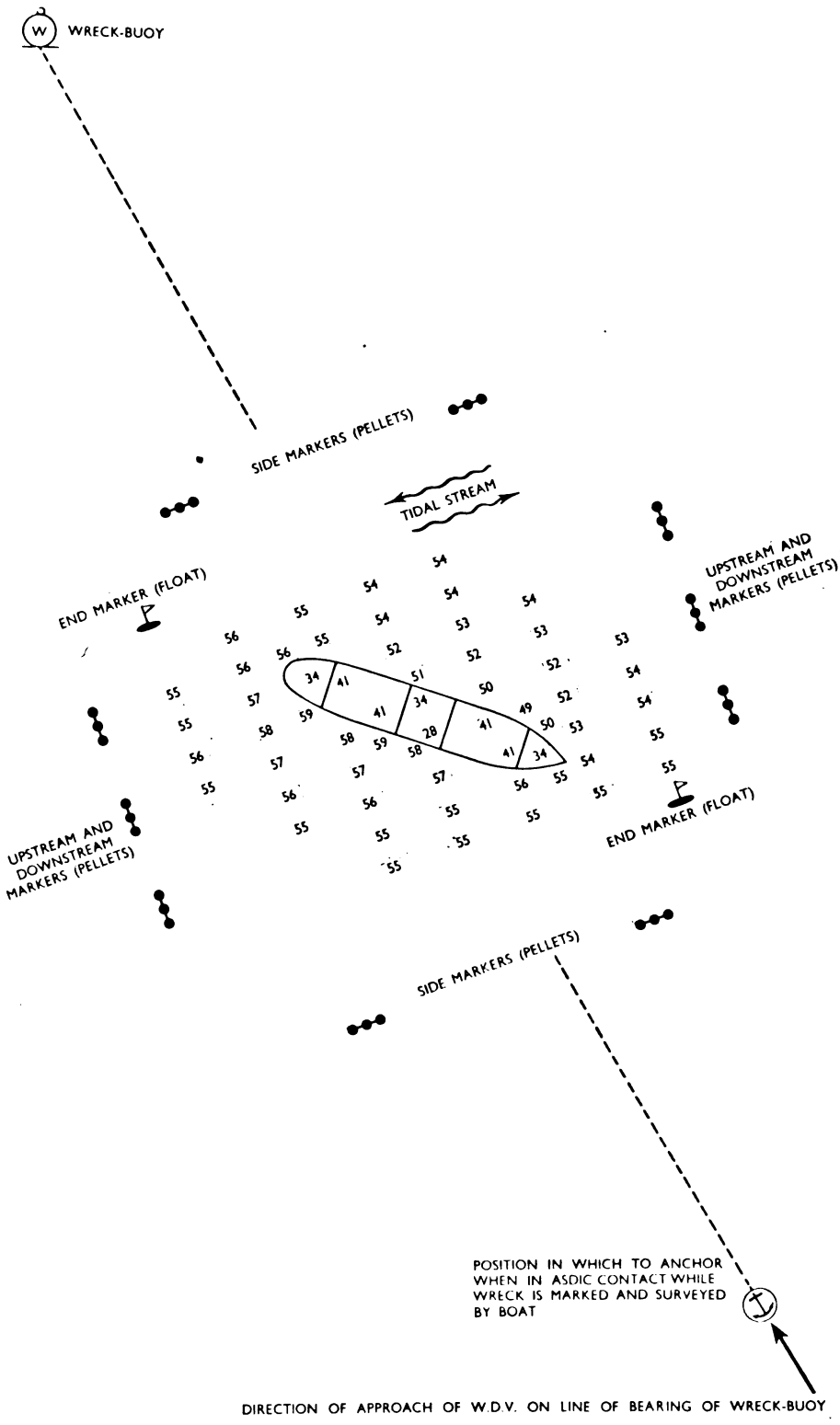
W
WRECK-BUOY
SIDE MARKERS (PELLETS)
TIDAL STREAM
END MARKER (FLOAT)
UPSTREAM AND DOWNSTREAM MARKERS (PELLETS)
UPSTREAM AND DOWNSTREAM MARKERS (PELLETS)
END MARKER (FLOAT)
SIDE MARKERS (PELLETS)
POSITION IN WHICH TO ANCHOR WHEN IN ASDIC CONTACT WHILE WRECK IS MARKED AND SURVEYED BY BOAT
DIRECTION OF APPROACH OF W.D.V. ON LINE OF BEARING OF WRECK-BUOY

Fig. 49. Example of marking and surveying a wreck before charges are laid. (Note the silting on the port side and the scouring on the starboard side).

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Surveying a Wreck

Full details of the wreck, the nature of its cargo and the manner in which it was sunk should, if possible, be obtained beforehand, and when it has been located an accurate survey of the wreck and its surroundings should be made. The more detailed the survey the more accurately can the charges be placed, and the sooner will the wreck be effectively dealt with.

A boat with echo-sounding equipment should make a series of parallel runs up and down stream, using one of the corner markers as a datum point, and so cover the wreck and its immediate vicinity. A clear plan of the area can then be made, showing such features as the overall size of the wreck, the number and heights of its " peaks," any wreckage attached to and suspended above the wreck, and any silting or scouring caused by the current or tidal stream. The best results from echo-sounding are obtained when the boat is going down stream, or at slack water.

Care should be taken to check the results of the survey with the details of the wreck previously obtained to see that they agree, and if necessary the survey should be extended beyond the immediate vicinity of the wreck because some wrecks have been found in two or more parts separated by as much as 200 yards.

After as thorough a survey as possible has been made by boat it is a good plan, if the depth of water allows, to check the details by a further survey made from the ship.

Methods of Dispersal

In deep water it may only be necessary to remove masts, funnels, derricks and top-hamper to get the required clearance over the wreck. This is best done by having the charges connected by a span at the required depth and then sweeping with them over the wreck and lowering the charges when their span fouls one of the " peaks."

On a soft bottom, when the whole wreck must be dispersed, it should be buried. If the survey shows scouring by the tides on one side of the wreck, charges should be placed alongside the hull on this side to deepen and lengthen the scour so that the wreck will sink bodily into it when assisted by a few charges laid along the other side.

The " grave " must be formed as quickly as possible so that the wreck will sink into it before the action of the tides can re-form the bottom. Charges are laid in pairs, two or four at a time at 20-ft. intervals, up to 40 being laid and fired in one " blow." (A 300-lb. depth-charge will make a crater 30 ft. wide and 10 ft. deep in 10 fathoms of water on a bottom of sand and mud.) If the wreck is broken in half one half should be buried before tackling the other half. Wrecks dealt with in this manner have been completely buried level with the original bottom.

On a hard bottom in which little impression can be made, charges should be laid all along the wreck to break it up. After several " blows " the wreck should have opened up sufficiently to allow other charges to be laid in the holds. If the wreck is stowed with a very solid cargo additional charges may have to be laid outside the hull to break it up and release the cargo.

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Large ships should be dealt with piecemeal, starting at one end and working towards the other, after which any remaining " peaks " can be dealt with separately. If a mast is showing above water it may be useful as a guide and so should be dealt with last of all.

A wreck can be dispersed in this manner so that no part of it will project more than six feet above a hard bottom.

Laying and Firing Charges by Boat

Experience has shown that charges can only be laid accurately by using an echo-sounder, and when the boat is stemming the stream or heading into the wind. Accuracy is impossible if the boat is allowed to drift across the wreck, because she is not then under control and cannot be kept in position while the charges are lowered.

In addition to being fitted with echo-sounding gear, the boat should have three fairleads along each side, each leading to its own cleat, and her hull should be metal-sheathed to withstand the chafe of the charges when they are slung over her sides.

The depth-charges are fitted with pistols and primers and then lashed together in pairs. Each pair is hooked to a lowering rope and then hoisted out to the boat, pistol ends uppermost; there each is slung outside the boat on a lowering rope, which is led in through one of the fairleads and belayed to its cleat. In very calm water with no tide a Service motor cutter can take four pairs of 300-lb. charges, one pair over each bow and one pair over each side amidships; but normally she can take only two pairs of 300-lb. charges (one over each bow), or four pairs of 175-lb. charges.

The boat then leaves the ship and heads for the wreck. When clear of the ship the crew insert the detonators into the pistols and lower the depth-charges to an initial depth of three fathoms so that they will not interfere with echo-sounding. The boat is then steered to pass over the wreck at very slow speed and stemming the tide until the echo-sounder indicates that the required position has been reached; the charges are then lowered to the bottom and cast off. Each lowering rope should be tailed with a 4-ft. length of chain with a special slip-hook on the end to which is hooked the sling of a pair of charges. When the charges reach the bottom the weight of the chain should trip the hook, thus releasing the lowering rope which can then be recovered.

The boat then returns to the ship for more charges, and the operation is continued until the last load of charges has been embarked. An electric firing-pistol is fitted in one charge of the last pair to be laid, this charge being known as the " firing charge ", because when it is fired electrically from the boat by means of electric cable and a dynamo-exploder, its explosion detonates the other charges.

The firing-charge should detonate any other charge within a radius of 40 feet.

The dynamo-exploder and its cable are not embarked until the firing-charge has been lowered and slung over the side of the boat. If two boats are used the boat with the firing-charge must not leave the vessel until the other boat is clear of the wreck. On no account must the firing-cable be allowed to touch

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an exposed part of the boat's electrical circuit, and both ends of the cable must be kept securely taped until, under the supervision of the firing officer, one end is connected to the firing-charge and the other to the dynamo-exploder.

When the boat is in position over the wreck one end of the firing-cable is connected to the pistol of the firing-charge, and the cable is paid out as the charge is lowered into position. After laying the firing-charge the boat goes slowly to a safe distance from the wreck (500 yards for forty 300-lb. charges), paying out the firing-cable as she goes.

Meanwhile, the parent vessel, flying a large red flag, proceeds to a safe distance from the wreck (one-and-a-half miles for forty 300-lb. charges), usually down stream, and then turns bows on to the wreck. After ensuring that any shipping in the vicinity is well clear, the parent vessel gives to the boat, by a simple one-letter signal code, the order " Fire when ready."

When this order is received in the boat the firing-cable is connected to the dynamo-exploder, the earth-plate is connected and lowered over the side, and finally the firing officer inserts the handle of the dynamo-exploder and fires the charge. The firing-cable is then recovered, care being taken, as at all times, to keep it clear of the boat's propeller.

If the parent vessel can be brought to within 200 yards of a well-marked wreck, a boat can lay charges as fast as they can be prepared, and with a well-trained crew 40 charges can be laid accurately and fired in under two hours.

Should a misfire occur the boat should recover as much of the firing-cable as possible while keeping at a safe distance from the wreck. She should then wait for at least ten minutes, then cut the cable and return to the parent vessel to embark another firing-charge together with a reel of firing cable.

If the depth of water is not greater than 60 feet, a 25-lb. charge, fitted with a 7-min.-delay Bickford safety-fuse, may be used in preference to another electrically fired charge. When over the wreck the fuse is lit and the charge dropped over the side of the boat, which then proceeds to a safe distance until the charge explodes.

Laying and Firing Charges from the Wreck Dispersal Vessel

In certain circumstances it may be quicker or more convenient to lay and fire the charges from the wreck dispersal vessel, particularly if only the upper parts of the wreck have to be dispersed, or if conditions are unsuitable for boat-work. There must, however, be a depth of at least seven feet of clear water between the vessel's keel and the highest peak of the wreck, and the charges must not be lowered to within less than six feet of the bottom to ensure that they will not be dragged along it.

Two pairs of charges, connected by a span two feet less than the beam of the vessel, are lowered to the required depth, one on each side of the ship abreast the echo-sounder (see Fig. 50). The charges are then swept over the wreck until they foul some part of it, when they are lowered to the bottom and slipped. When sufficient charges have been laid in this manner they are counter-mined by exploding a 25-lb. firing-charge fitted with a 7-min.-delay Bickford fuse, No. 11, which should be exploded not more than 35 feet away from the other charges.

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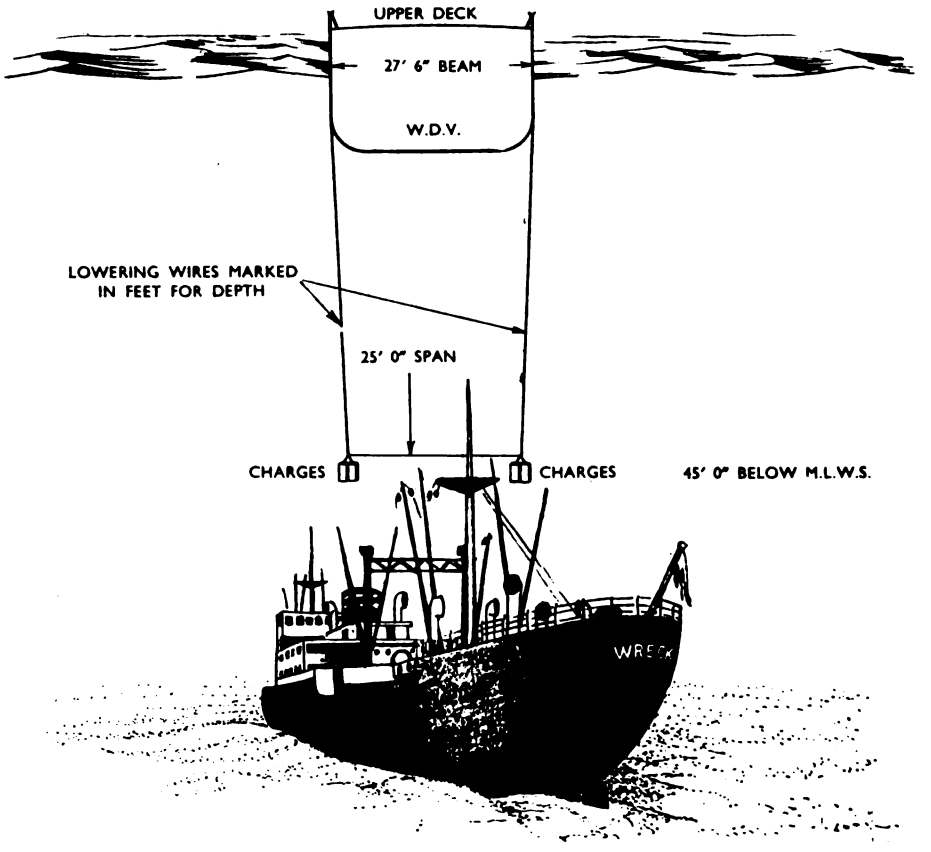

Fig. 50. Laying depth charges from a wreck dispersal vessel by sweeping them over the wreck

To lower the charges under the ship the ends of the two lowering-ropes are hooked to their respective pairs of charges and connected by their span. The span, suitably weighted to ensure that it sinks, is cast over the bows and hauled abaft the forefoot, and each pair of charges is lowered from each bow to a depth of at least seven feet below the keel. The lowering-ropes are then fleeted aft to suitable cleats abreast the echo-sounder and the charges are lowered to the required depth, which should be at least two feet below the highest peak of the wreck.

Another method is to reeve a bottom-line and with it to haul one of the lowering-ropes under the vessel abreast the echo-sounder. Both pairs of charges are placed abreast this lowering-rope but on the side opposite its hauling part, and the lowering-ropes and span are connected as before. The first pair of charges is then lowered on the span and hauled by its lowering-rope under the vessel, being followed by the second pair of charges which is lowered by its lowering-rope (see Fig. 51).

When the charges have been lowered to the required depth the vessel steams very slowly upstream towards the wreck; in a stream of 1½ knots a speed of about half a knot can be made good while still maintaining steerage

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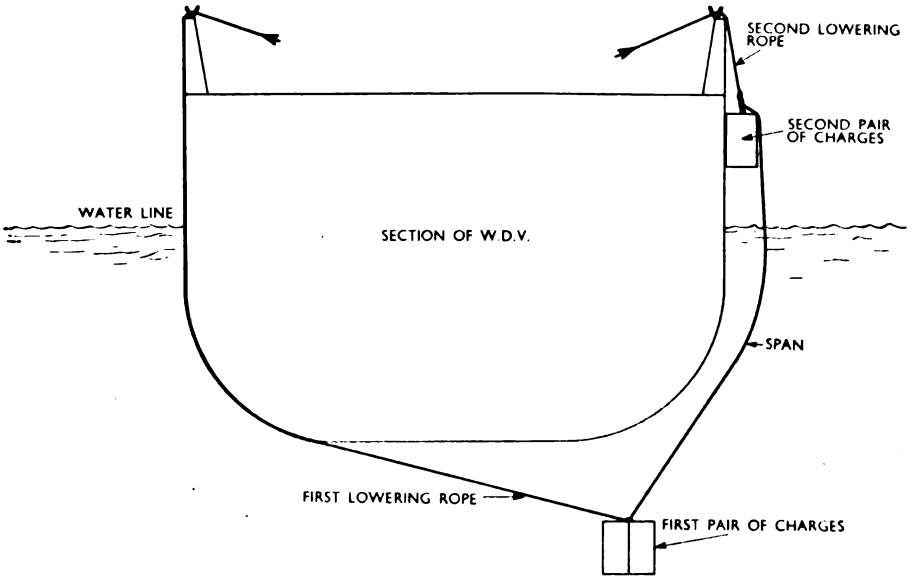

Fig. 51. Method of lowering charges under the wreck dispersal vessel, using the first lowering-rope rove as a bottom-line

way and without the charges trailing too far aft. By manœuvring the vessel so that she creeps ahead and astern and at the same time traverses the area between the markers, the span must eventually foul the peak of the wreck. As soon as the men tending the lowering-ropes feel the span foul the wreck they lower the charges to the bottom and slip them.

Charges can be laid from the wreck dispersal vessel in winds of up to force 5 unless there is a heavy swell. In good weather two sets of four charges each can be laid at the same time, and in this way eight charges can be prepared and laid every 40 minutes. If the depth is less than ten fathoms, the vessel proceeds upstream after laying the required number of charges, then turns and heads for the wreck at a speed of at least nine knots. Just before she passes over the wreck the 25-lb. firing-charge is dropped and the vessel then carries on down stream until the charge explodes. Should a misfire occur another firing-charge is dropped after an interval of at least 30 minutes has elapsed.

The Bickford safety-fuse will not function in depths of over ten fathoms, and in these circumstances the firing-charge must be laid with a sinker, like a moored mine (see Fig. 52), to ensure that it will be effective. The 25-lb. firing-charge is lashed to two pellets, and a mooring-rope with a 1¾-cwt. sinker is attached to the charge, the length of the mooring-rope being adjusted so that when the sinker is on the bottom the pellets and the charge will be at a depth of not more than 60 feet below the surface. The charge is then dropped in the manner already described and it should explode close enough to the other charges to detonate them. If a misfire occurs, another firing-charge can be laid in the same way after an interval of 30 minutes, and its explosion should be sufficient to crush the pellets of the original firing-charge and so cause it to sink.

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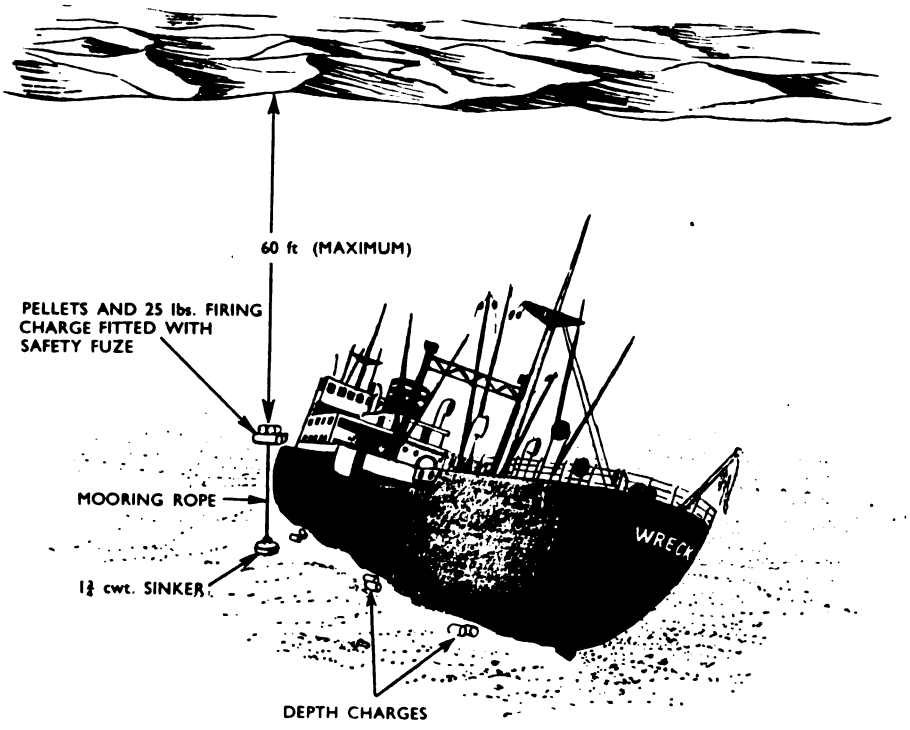

Fig. 52. Method of laying a firing-charge in a depth of more than 60 feet

Safety Precautions

It is of the greatest importance that familiarity in handling explosives must never be allowed to lead to carelessness. Particulars of the explosives used and the methods of handling and fitting them, together with the precautions to be observed, are given in detail in the *Demolition Drill Book* and the *Naval Magazine and Explosive Regulations*, and the instructions therein must be strictly observed.

Great care should be taken to instruct the crew fully in their respective duties, when fitting pistols and primers, for example, and attaching the lowering-ropes, and an officer should personally supervise the fitting of charges and pistols. The detonators should never be fitted until the charges are slung over the side of the vessel laying them and they are ready for lowering. When a boat is used for laying, the electrical equipment, such as batteries and signalling lamps, should always be kept in the after part, abaft the echo-sounder, and all charges and electric firing-leads should be kept in the fore part. The handle of the dynamo-exploder should always be kept personally by the firing officer.

Precautions when Operating Inshore

The effects of underwater explosions when close inshore depend largely on the nature of the bottom and of the land, and before operating within about three miles of an inhabited area consideration must be given to the possibility of injuring any bathers or damaging buildings. In such circumstances the

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local civilian authorities, such as the Town Clerk, Chief of Police and Harbour Master, should be given adequate warning of the date on which operations are likely to begin, and they should be advised that the vessel will fly a large red flag while working with explosive charges.

The table below gives the safe ranges from a bathing beach at which various charges can be exploded, and these should be taken as the absolute limits of safety.

NUMBER OF 300-LB. CHARGES EXPLODED SIMULTANEOUSLY	MINIMUM SAFE DISTANCE FROM NEAREST BATHING BEACH :	
	IF FILLED WITH AMATOL OR T.N.T.	IF FILLED WITH MINOL
	naut. miles	*naut. miles*
2	1	1¼
4	1¼	1½
6	1½	1¾
10	1¾	2
14	1¾	2
20	2¼	2¼
30	2½	2¾
40	2¾	3

In certain circumstances buildings are more vulnerable than bathers, and this table should not be applied to buildings. In one instance blows of only four charges in six fathoms on a soft sandy bottom three miles off shore caused complaints from householders. If there is any doubt about the results of an explosion the number of charges in a blow should be reduced, and an officer should be landed to observe the effects of the first blows.

Checking the Clearance over a Wreck by Sweeping

Echo-sounding cannot be relied upon to locate masts and other narrow peaks of a wreck, so for this, and finally to ensure that the wreck has been cleared to the required depth, a sweep must be used, either from the vessel or from a boat.

Before sweeping is begun the wreck area must be re-marked to ensure that the wreck dispersal vessel or her boats will pass over the wreck, and a boat should be near the wreck ready to lay a marker immediately the sweep fouls an unsuspected peak. The sweep most commonly used for this purpose is the " drift-sweep," consisting of three or four lengths of quarter-inch chain marked in fathoms and feet and hung from the gunwale ; the lower ends of the chains are weighted with sinkers and joined by a span of small wire or spunyarn (see Fig. 53 (i)).

To work the sweep the wreck dispersal vessel goes upstream of the wreck, turns athwart the stream with the sweep rigged along her upstream side, and then drifts broadside down to the wreck while working her echo-sounder and adjusting her position by moving the engines ahead or astern as required. The echo-sounder will indicate the moment when the vessel passes over the wreck.

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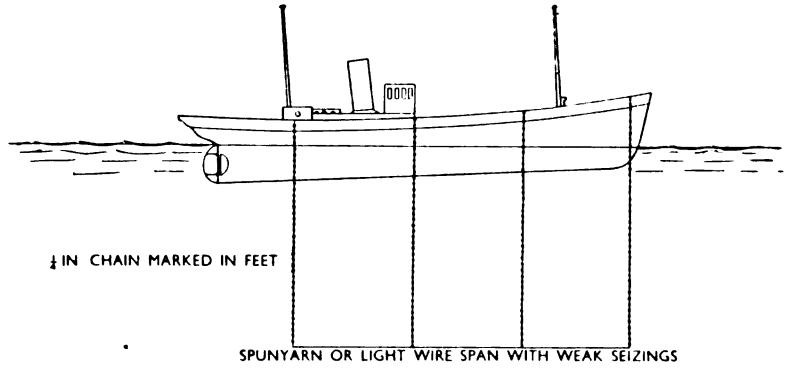
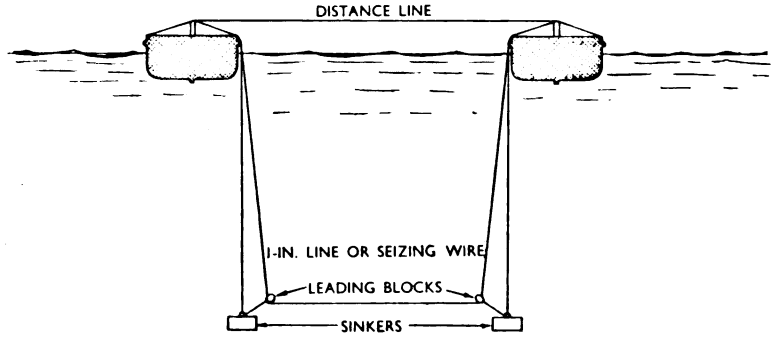
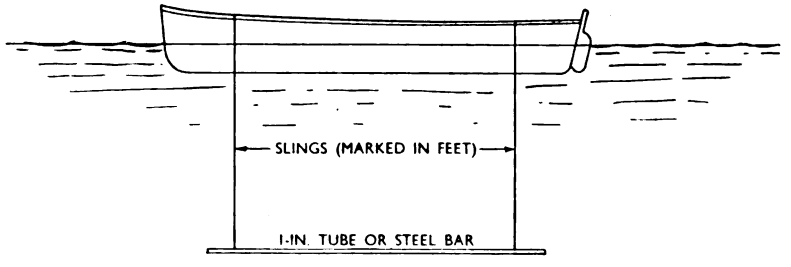


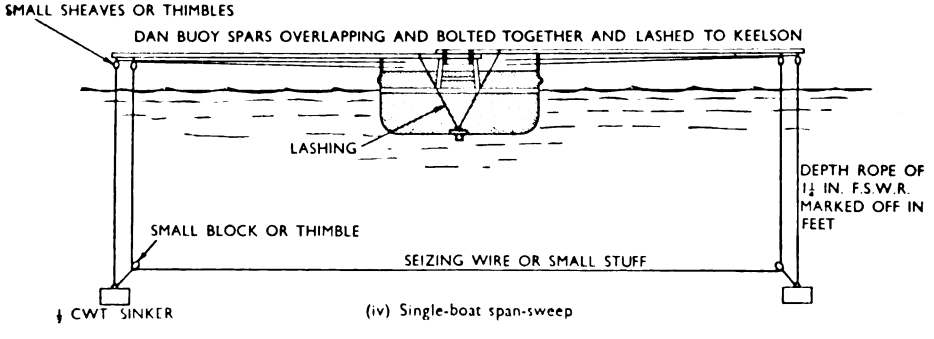
(i) Chain-sweep slung from wreck-dispersal vessel



(ii) Two-boat span-sweep



(iii) Single-boat bar sweep


SMALL SHEAVES OR THIMBLES
DAN BUOY SPARS OVERLAPPING AND BOLTED TOGETHER AND LASHED TO KEELSON
LASHING
DEPTH ROPE OF 1½ IN. F.S.W.R. MARKED OFF IN FEET
SMALL BLOCK OR THIMBLE
SEIZING WIRE OR SMALL STUFF
¼ CWT SINKER

(iv) Single-boat span-sweep

Fig. 53. Types of sweeps

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When the sweep fouls the wreck the chains will grow out noticeably from the vessel's side, until the span joining its ends parts.

If no part of the wreck is fouled by the sweep, the process should be repeated as often as necessary, with the sweep lowered a foot each time, until the sweep does foul the wreck, and the clearance over the wreck can thus be gauged to within one foot.

Where the wreck dispersal vessel cannot be taken over the wreck a boat-sweep must be used. If there is enough sea-room it is best to use two boats towing a " chain-sweep " between them, as described in Chapter VII of Volume II of this manual, or the " span-sweep " illustrated in Fig. 53 (ii). If only one boat is available a " bar-sweep " can be used consisting of a bar or tube slung below the boat by two lowering-ropes marked in fathoms and feet (see Fig. 53 (iii)).

Another type of single-boat-sweep is that illustrated in Fig. 53 (iv). This consists of two Dan-buoy spars lashed or bolted together and shipped in long-shanked crutches athwart the boat to form an outrigger on each side, thus supporting and extending the sweep below the boat at the required depth.

Further details of sweeping, and methods of reducing soundings to Mean Low Water Springs, are given in the *Admiralty Manual of Hydrographic Surveying.*

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CHAPTER XI

Extempore Handling of Heavy Weights

IN CHAPTER VI of Volume II of this manual the erection and rigging of extempore lifting gear on board a ship is described in detail. The seaman may, however, be called upon to land heavy stores or equipment at places where normal dockside equipment such as cranes, railways and motor transport is not available, and he may have to do this solely with his own ship's gear, perhaps supplemented by anything he can find ashore.

Extempore methods of lifting heavy equipment on shore by means of gyns, derricks and sheers are very similar to those used on board a ship, and the usual method of extempore transport is by sleighs mounted on rollers. In this chapter some methods of erecting, rigging and working extempore lifting gear, and of transporting heavy equipment by sleigh are described, and some remarks on the construction of rafts are also included.

GYNS, DERRICKS, SHEERS, AND ROPEWAYS

The gyn is a tripod formed by three spars with their heads lashed together; the swinging derrick consists of an upright spar with a swinging boom pivoted at its foot; the derrick is a single upright spar; sheers consist of two upright spars with their heads lashed together and their feet splayed out; and a ropeway consists of an overhead span of rope set up between two sheers or gyns along which a travelling block is hauled back and forth.

Uses and Limitations

THE GYN

The heads of the three spars are lashed together so that the head of one rests between the heads of the other two; the centre spar is called the "prypole" and the other two the "cheeks." The gyn provides a vertical lift, to a height limited by its tripod structure and the bulk of the load, and any movement of the load forward, sideways or backward is limited to the triangular area enclosed by the legs of the gyn. A suspended load may be hauled straight towards the centre of the cheeks or towards the prypole without risk of upsetting the gyn, but hauling the load to one side, or taking a swinging lift, is liable to capsize the gyn, and on no account should the lower block of the purchase be allowed outside the lines joining the prypole to the cheeks.

Although a gyn does not need to be guyed it is cumbersome and limited in its scope compared with a derrick, and it is therefore used only for vertical lifts and light loads of up to about three tons, or for erecting heavy derricks or sheers.

THE SWINGING DERRICK

This can lift loads and swing them through a maximum arc of 120 degrees, and compared with a derrick it is more easily handled and provides quicker working. Its lift is limited by the length of its boom, however, and this in turn is limited by the length of the upright spar and the strength of the snotter supporting the heel of the boom. The boom and the snotter may be unduly

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stressed when the boom is topped right up under load, and the topping lift, back guy and upright spar may be unduly stressed when the boom is horizontal and under load. The best working condition is with the boom topped at an angle of 45 degrees. The upright spar needs to be fully guyed or supported by a prypole.

A swinging derrick is more complicated in rig than either a derrick or sheers, and because of its limited lifting capacity it is only used for light loads of up to about 1½ tons. It is particularly useful for disembarking stores from a boat onto a jetty.

The Derrick

A derrick is simpler to rig than sheers or a swinging derrick, and it can raise a load almost to its own height and slew it over a considerable distance. It needs to be fully guyed, however, both forward and aft and sideways. When lifting a load a heavy stress is imposed on the back guy, and when slewing a load a heavy stress is imposed on the guy farthest from the load, and these guys must therefore be particularly strong and secure.

Because of the limited strength of the spars and gear which are normally available a derrick is usually limited to hoisting and slewing weights of up to 14 tons. A light derrick is often used for erecting a heavy derrick or sheers.

Sheers

These are more cumbersome than a derrick to rig and erect, but for a given size of spar they can lift nearly twice as heavy a load. They are stable laterally and so need only a fore guy and a back guy. They can raise a load almost to their own height, but any movement of the load must be confined to a fore-and-aft direction midway between the legs and towards their feet or just behind them. Any lateral movement of the load is liable to capsize the sheers.

Sheers are therefore used for heavy lifts which do not need to be slewed, and because they require foothold on one side of a weight only they are particularly suited for use on the edge of a wharf or the bank of a river. Light sheers may be used instead of a gyn or a derrick for erecting a heavy derrick or sheers.

The Ropeway

This is used to transport loads across a river or a ravine. Gyns are preferable to sheers as supports for the overhead span because they are more stable and need less guying. An extempore ropeway is usually confined to transporting light stores and equipment because of the heavy stresses set up in the span when transporting a load; a 200-ft. 3-in. F.S.W.R. span, for example, is limited to a maximum load of only 22 cwt., using a factor of safety of four.

Limits of Movement of Derricks and Sheers

The maximum lift of a derrick or sheers is limited by the length of the longest fall available for the main tackle, which for heavy lifts is usually a three-fold purchase. Hawser-laid cordage is usually issued in coils of 120 fathoms, so if the fall is of cordage the maximum lift, allowing a suitable length for the hauling part, will be about 90 feet.

Sheers and derricks should not normally be inclined to a greater angle than 20 degrees from the vertical, and at this angle they can pick up a load

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at a distance from their feet of one-third of their effective length (the effective length of a derrick or sheers being the distance from the ground to the point of attachment of the main-tackle sling).

Provided that sheers are adequately guyed in a fore-and-aft direction they can traverse a load from a position before them straight between their feet to a position behind them. Provided that a derrick is adequately guyed both fore-and-aft and sideways it can slew a weight through a full circle.

Guys

The guys of derricks and sheers, particularly those used for heavy loads, will stretch considerably when under load, and all guys must therefore be working guys so that their tensions can be adjusted and any slack in them be taken down. When picking up a load a derrick or sheers should be heeled to a few degrees less than the required angle to allow for the stretch in the back guy; with heavy sheers this allowance may be as much as seven or eight degrees.

For light derricks or sheers the guys are usually pendants tailed with luff tackles, but for heavy derricks and sheers the guys should be runners rove through blocks at the head of the derrick or sheers and tailed at their hauling ends with luff tackles or two-fold purchases.

The fore and back guys of sheers should lie as nearly as possible in the fore-and-aft line of the sheers because any lateral deviation from this line will place undue stress on one of the legs and will also tend to capsize the sheers. The fore and back guys of a derrick should lie as nearly as possible along the line joining the heel of the derrick to the load it is to lift, and the side guys should lie as nearly as possible along a line passing through the heel of the derrick and at right-angles to the fore-and-aft guys.

If sheers are required only to traverse a load as far as their feet, the fore guy acts only as a preventer and may therefore be about half the strength of the back guy, but if the load is to be traversed to a position behind their feet the fore guy must be as strong as the back guy. If a derrick is required to slew a load through an angle of less than 90 degrees the side guy on the slewing side and the fore guy act only as preventers and so need not be so strong as the other two guys, but if the slewing angle is 90 degrees or more all guys should be of equal strength.

The angle of slope of a guy should not be steeper than one in two (about 25 degrees), otherwise any downward pull in the guy will put an undue stress on the derrick or sheers and any upward pull in it will tend to draw its holdfast from the ground. If a buried baulk of timber, or an anchor laid offshore, is used as a holdfast the slope of the guy should not be steeper than one in three (about 20 degrees). In a confined area it may be necessary to reduce the effective length of a derrick or sheers to obtain the correct lead for the guys, but this should not be done if the derrick or sheers has then to be heeled excessively to pick up the load; in such a case it is better not to reduce the effective length but to strengthen the guys and their holdfasts.

To give the guy a slope of one in two on firm and level ground the distance of a holdfast from the foot of a derrick or sheers should be twice the effective length of the derrick or sheers, and to give a slope of one in three it should be three times the effective length. To obtain the correct lead for the guys on sloping ground the uphill and downhill holdfasts must be placed respectively closer to and farther from the foot than normally (see Fig. 54).

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If a guy holdfast is inaccessible, an anchor laid offshore, for example, the hauling part of the guy tackle must be led to the head of the derrick or sheers and thence to the foot.

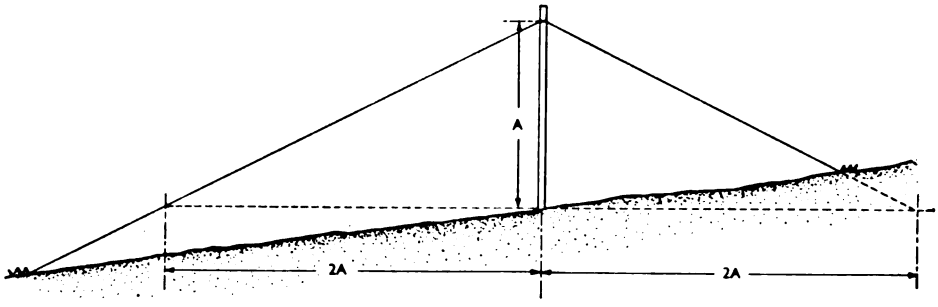

Fig. 54. Correct lead for guys on sloping ground

Shoes

Shoes are not necessary if the load is light and the spars are stepped on hard ground or thick concrete, but for heavy loads and on any but a firm footing the heels of the spars should be stepped in shoes. A shoe for a light derrick or sheers is usually a square slab of hardwood with a recess in its upper surface to take the heel of its spar, and each of its sides should be not less than four times the diameter of the spar. For heavy derricks or sheers the shoe is of metal or made up from baulks of timber. The shoe should bear on firm ground and be sunk level with the surface. In soft ground the earth under the shoe should be well rammed or the shoe supported on baulks of timber, and it should be held in place by pickets driven at intervals along its sides and with their heads flush with the shoe. Shoes of sheers and gyns must be as nearly as possible at the same level otherwise an undue stress will be placed on one of the legs, and the sheers or gyn will then tend to capsize.

Heel Tackles

When erecting a heavy derrick or sheers heel tackles should be rigged to prevent the heel of the spar (or spars) from sliding backwards as it is hauled upright. For sheers one heel tackle for each spar should be sufficient ; they are usually led from a common holdfast placed so that the angle between the tackles is about 20 degrees. For a derrick two heel tackles should be provided and led to two holdfasts placed so that the angle between the tackles is about 20 degrees.

Heel tackles are also necessary when working the derrick or sheers, and particularly when the shoes are embedded on sandy soil or the spars are stepped without shoes on hard ground or concrete. If sheers are required only to traverse a load as far as their feet one heel tackle for each spar should suffice, each being led to its own holdfast directly in front of its foot ; but if the load is to be traversed to a position behind the sheers two heel tackles for each spar must be provided, one leading directly forward and the other leading directly backward. If a derrick is required to slew a load through an angle of less than 90 degrees two heel tackles should suffice, one leading in the direction of the fore guy and the other in the direction of the side guy towards which the load

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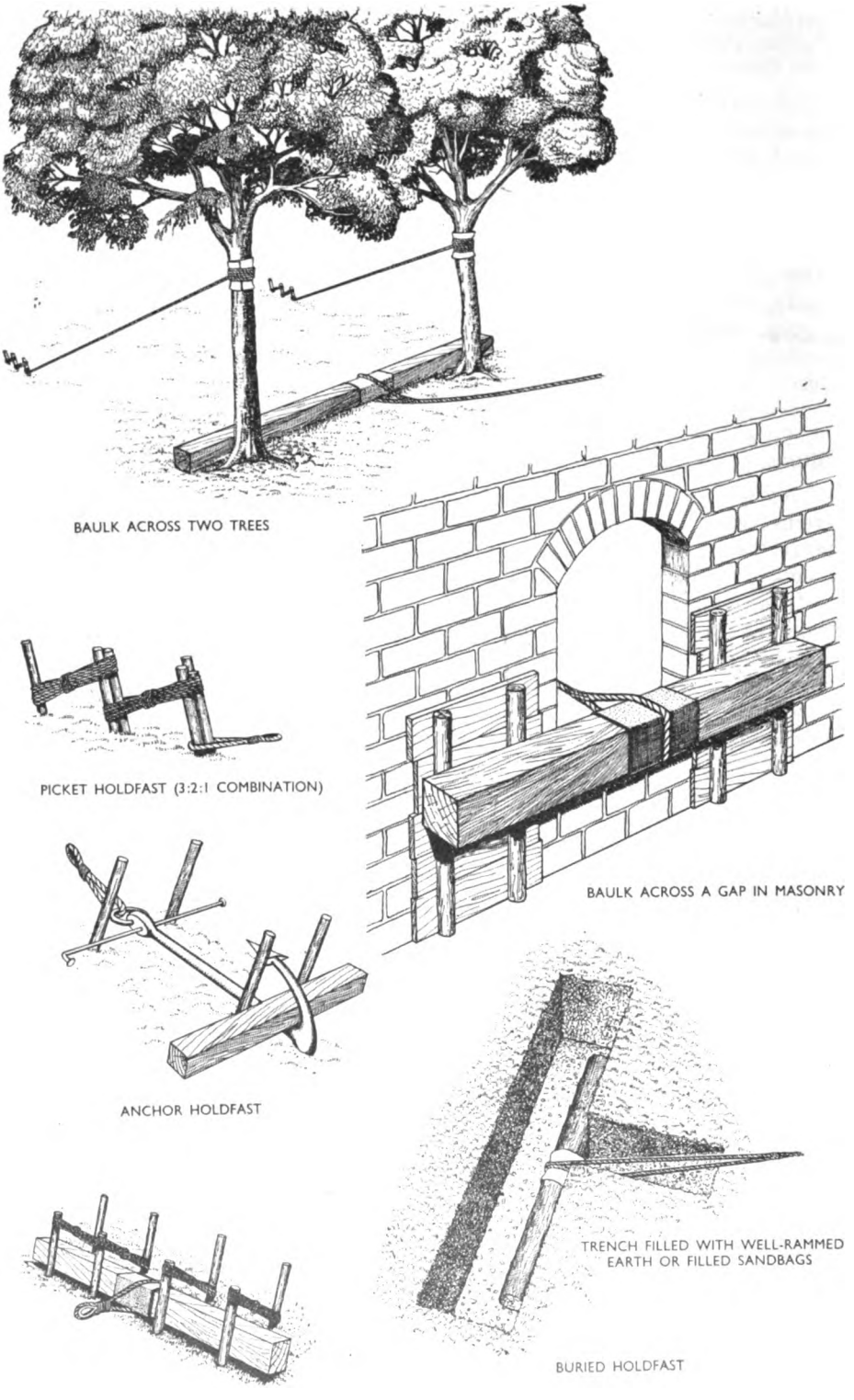
BAULK ACROSS TWO TREES
PICKET HOLDFAST (3:2:1 COMBINATION)
BAULK ACROSS A GAP IN MASONRY
ANCHOR HOLDFAST
TRENCH FILLED WITH WELL-RAMMED EARTH OR FILLED SANDBAGS
BURIED HOLDFAST
BAULK AND PICKET HOLDFAST

Fig. 55. Types of holdfasts

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is to be slewed ; but if the load is to be slewed through an angle of more than 90 degrees, four heel tackles should be provided leading in the directions of the four guys.

Anti-twisters

All tackles are liable to twist when under load owing to the lay of the rope, particularly long tackles and those rove with new rope. To prevent this the fall of a tackle should be well stretched and any resulting turns removed before it is rove, and an anti-twister, such as a stake, should be inserted between the running parts of the fall and secured to its standing end below the block. For a guy tackle a heavy maul has proved effective, the weight of the head countering the tendency of the tackle to twist ; for a lifting tackle a handspike should be lashed between the running parts below the upper block and fitted with a steadying line at each end.

Holdfasts

These provide the anchorages for the standing blocks of the guys and tackles and also the anchorages for capstans and winches. Holdfasts may consist of any of the following :—

(i) existing natural or structural features such as trees or masonry ;
(ii) pickets driven singly or in combination into the ground ;
(iii) baulks of timber placed behind a line of driven pickets ;
(iv) ships' anchors embedded in the ground and held by driven pickets, or laid under water in the normal way ;
(v) baulks of timber buried in trenches dug in the ground.

Whatever the type of holdfast used it must be more than strong enough for the stress it is intended to bear, because once a holdfast starts to give it is difficult to strengthen it. A holdfast must be so arranged that the maximum resistance it can offer is in line with the stress it must bear ; a buried baulk of timber, for example, should lie at right-angles to the pull, whereas a combination of pickets should be driven exactly in line with the direction of the pull.

Existing holdfasts should be used whenever practicable if they are conveniently situated and strong enough for the job. The holding power of a tree is uncertain because so much depends on the depth of its roots and the nature of the soil ; a tree can be considerably strengthened, however, by fitting it with a back guy, and if two trees are growing close together their combined holding power can be used by placing a baulk of timber across them.

A baulk of timber placed across a gap in masonry makes a good holdfast, provided that the stress is distributed over a sufficiently large area of the masonry by placing planks vertically and horizontally between the baulk and the masonry.

The pier of a bridge or the base of a tower can be used by encircling it with a strop, but care should be taken to protect the strop from chafe and bad nips.

Picket holdfasts may be used in ordinary soil for pulls not exceeding two tons. The normal picket is an ash stake five feet long and three inches in diameter, with one end pointed and shod with iron and the other end bound with an iron hoop ; it should be driven to a depth of three feet at an inclination of about 20 degrees with the vertical. Pickets may be used singly or lashed together in combinations of one-and-one, two-and-one, or three-two-and-one, as shown in Fig. 55.

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A baulk and picket holdfast consists of a baulk of timber placed behind a line of driven pickets which are backed by another line of pickets, and it may be used for pulls of between two and ten tons. Only two lines of pickets should be used, driven-in in combinations of one-and-one or two-and-one, with each combination at least 18 in. from the next. A three-two-one combination of pickets should not be used because of the difficulty of driving the pickets so that each will bear its fair proportion of the stress. The front row of pickets should be exactly in line so that the stress on the baulk is divided equally among them, and the ground under the baulk should be cut away to allow the face of the baulk to bear fairly against the inclined pickets (see Fig. 53). The baulk should be well parcelled where the strop passes round it.

An anchor holdfast consists of an Admiralty pattern anchor embedded and supported by pickets, as shown in Fig. 55, and if the pull is horizontal it will take a stress up to the strength of its ring. It is not very suitable as the holdfast for a guy because the upward pull of the guy tends to dislodge the anchor.

When an offshore underwater holdfast is required for the fore guy of a derrick or sheers the anchor should be laid in a position which gives the guy plenty of scope, and its angle of slope should not be steeper than one in three; that part of the guy which will be under water should be of chain. Backing one anchor with another does not provide greater holding power unless the anchors are laid far apart from each other.

A buried holdfast is used for pulls of over ten tons and consists of a baulk or baulks of timber laid in a trench and then covered with well-rammed earth. The trench should be two feet longer than the baulk and have a vertical face; its depth will depend on the nature of the soil and the pull which the holdfast is required to withstand. A subsidiary trench to take the strop must be cut as shown in Fig. 55; its slope should not be steeper than one in three and chocks should be placed to support the baulk clear of the bottom of the trench to enable the strop to be passed. Planks can be laid vertically and horizontally between the baulk and the face of the trench to distribute the stress over a greater area.

Raising Derricks and Sheers

The various methods of raising a derrick are described here, and they can be applied equally well to sheers. It is assumed here that the derrick is fully rigged with its head lashing, main tackle, guys and foot tackles, and that its heel is pointed towards its shoe. As the derrick is swayed up the side guys must be tended to keep the head in the fore-and-aft line, and the heel tackles must be tended to guide the foot into the shoe and then to prevent it from slipping. Before the derrick becomes vertical the fore guy must be tended to prevent the derrick from falling backwards.

A derrick is hauled upright mainly by its back guy, but its head must be first raised high enough to allow the pull of the guy to exert an effective leverage without putting undue stresses on the guy, the derrick and its heel tackles. The head of the derrick must therefore be raised initially by some means until the angle between the back guy and the derrick is between 15 and 20 degrees; the greater this angle the less will be the stresses involved, and *vice versa*.

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By Manhandling

The head of a light derrick can be manhandled to the required height by means of a long handspike placed under and athwart the derrick head, which is then lifted by two or more men on each end of the handspike. A low trestle should be placed under the derrick and worked towards its heel with each lift until the head of the derrick has been raised high enough.

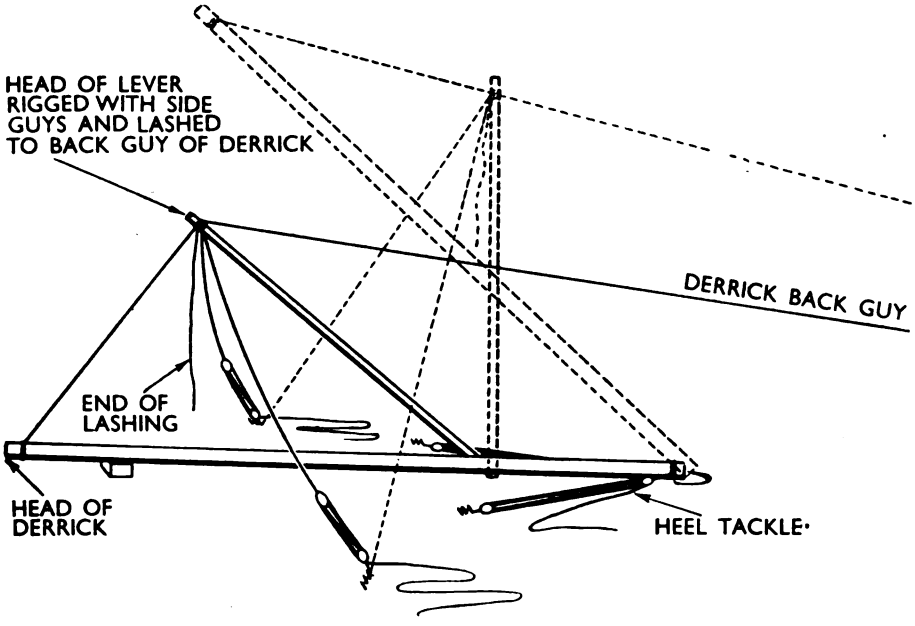

Fig. 56. Raising a derrick by a moving lever

By Moving Lever

This method is suitable for a derrick which is rather too heavy to be raised initially by manhandling, and which is fitted with a back guy consisting of a pendant tailed with a tackle. The lever should be a light spar about half as long as the derrick and fitted with side guys, and it is placed alongside the derrick with its heel at about a quarter of the way from the heel of the derrick to its head. The head of the lever is then lashed to the back guy at a position which will allow it to be raised through an angle of at least 45 degrees before it begins to raise the head of the derrick (see Fig. 56). The lashing is made with figure-of-eight turns and finished with a slip knot, and its end should be long enough to enable the lashing to be slipped from the ground as soon as the lever ceases to act.

The head of the lever is raised initially by manhandling and then by the back guy, while its head is kept over the derrick by means of its side guys. When the lever has been raised through an angle of about 45 degrees it will begin to raise the derrick and will continue to do so until it is a little beyond the vertical, when it will cease to act. At this stage the lashing is slipped and the lever is withdrawn, otherwise it will be lifted off the ground as the derrick is raised by its back guy.

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By Standing Lever

This method is suitable for a rather heavier derrick which is fitted with a back guy rigged as a runner and tailed with a purchase. The lever can be a spar or light sheers, and its length and position in relation to the derrick are the same as those for a moving lever. The lever is fully guyed with strong fore and back guys and is fitted with an extra guy on the side where the hauling part of the back guy is rove. If the lever is a spar a slot is cut in its head into which is placed the standing part of the back guy; if sheers are used as a lever the

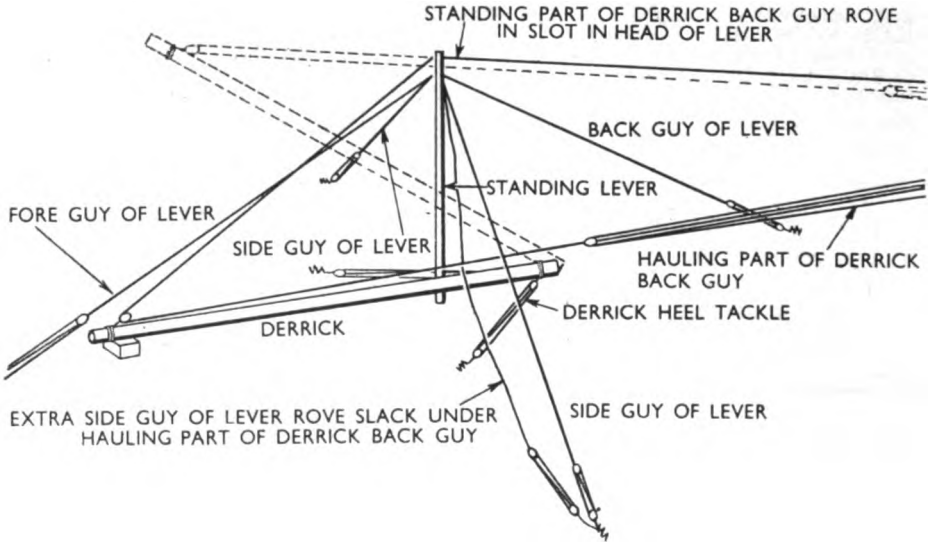
STANDING PART OF DERRICK BACK GUY ROVE IN SLOT IN HEAD OF LEVER
BACK GUY OF LEVER
STANDING LEVER
FORE GUY OF LEVER
SIDE GUY OF LEVER
HAULING PART OF DERRICK BACK GUY
DERRICK HEEL TACKLE
DERRICK
EXTRA SIDE GUY OF LEVER ROVE SLACK UNDER HAULING PART OF DERRICK BACK GUY
SIDE GUY OF LEVER

Fig. 57. Raising a derrick by a standing lever

standing part is placed over the crutch. The lever is then raised and its guys are set up, except the additional side guy which is rove ***underneath*** the hauling part of the back guy and left slack.

The derrick is then raised by hauling in on its back guy, and as the head rises so the hauling part of the back guy will rise until it fouls the side guy of the lever. Raising the derrick is then halted while the additional side guy of the lever is set up and the other side guy is cast off. The raising of the derrick is then completed by its back guy.

By Auxiliary Derrick

This method is used to raise the heaviest derricks and sheers. The position of the auxiliary derrick relative to the main derrick is important because the stresses involved in raising may approach the limits of the strength of the gear. The nearer the auxiliary derrick is to the head of the main derrick the less will be the stresses in the auxiliary derrick, but the less also will be its initial lift, and so a greater pull will be required on the back guy to continue the raising. Conversely, the farther the auxiliary derrick is from the head of the main derrick the greater will be the stresses on the auxiliary derrick, but the higher will be its initial lift and so a lesser pull will be required on the back guy to continue the raising. The best position for the auxiliary derrick in relation to the main derrick is given by the following formula, in which it is assumed that

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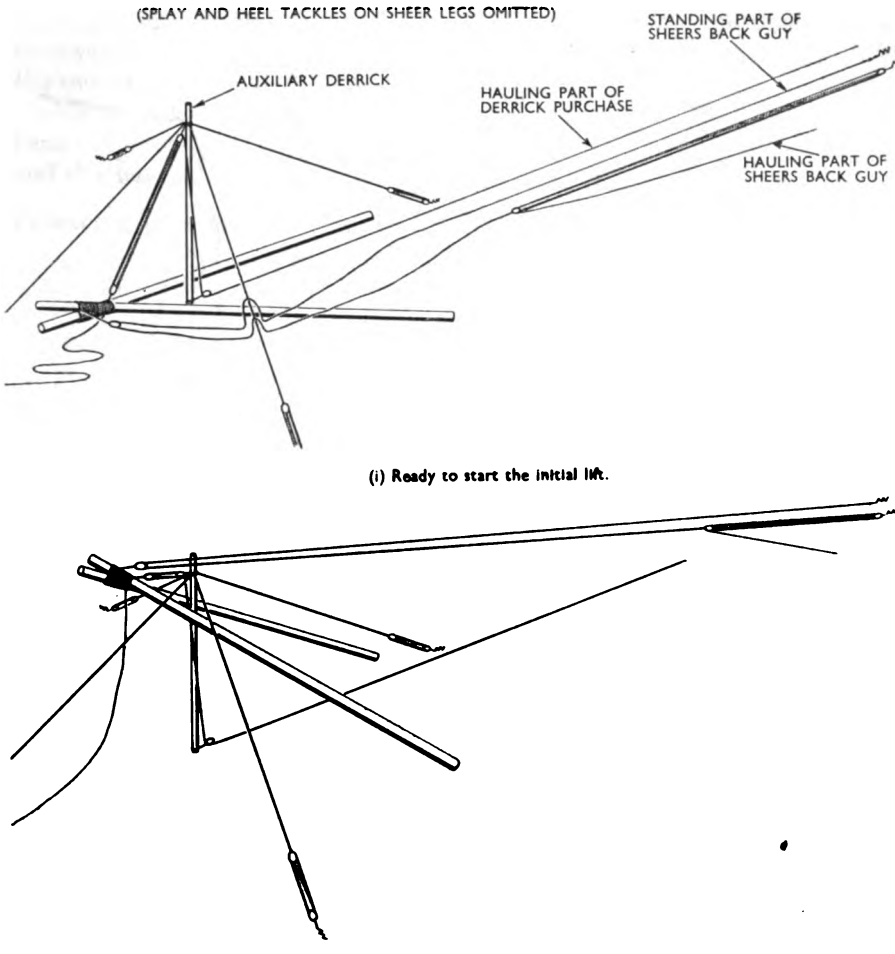
(SPLAY AND HEEL TACKLES ON SHEER LEGS OMITTED)
STANDING PART OF SHEERS BACK GUY
AUXILIARY DERRICK
HAULING PART OF DERRICK PURCHASE
HAULING PART OF SHEERS BACK GUY

(i) Ready to start the initial lift.

(ii) Initial lift by auxiliary derrick nearly completed
Raising continued by back guy.

Fig. 58. Raising sheers by an auxiliary derrick

the purchase of the auxiliary derrick is hooked to the main derrick at its head lashing :—

$$D = \sqrt{(A^2 - B^2)} \text{ less } 18 \text{ in.}$$

where :—

D is the distance in feet of the heel of the auxiliary derrick from the heel of the main derrick ;

A is the effective length in feet of the main derrick ; and

B is the effective length in feet of the auxiliary derrick.

(The distance of 18 in. represents the width of the auxiliary derrick's purchase.)

The auxiliary derrick must be fully guyed and rigged with an additional side guy for the same reasons as those given for a fixed lever, and if heavy it may itself

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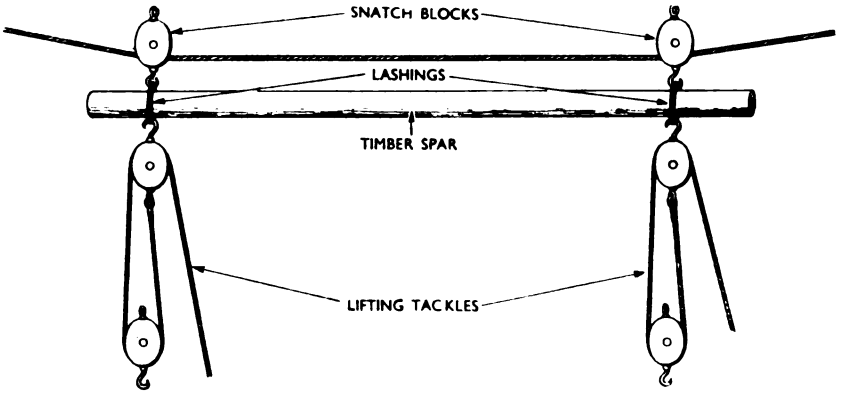

Fig. 59. Traveller for slinging heavy weights on a span

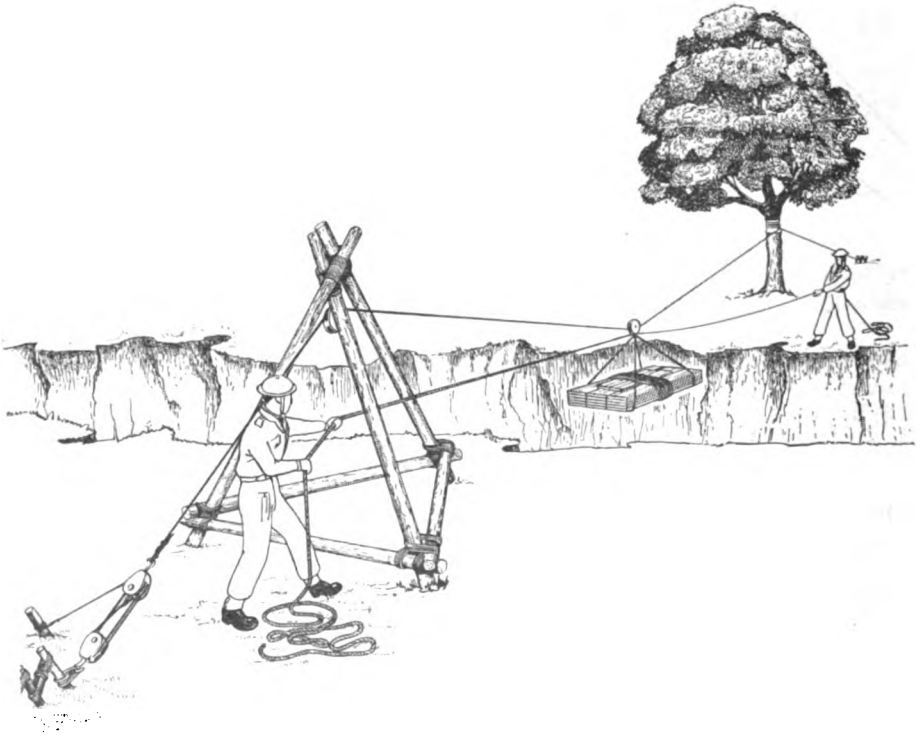

Fig. 60. A simple ropeway

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have to be raised with the help of a lever. When raised it should incline a little backward from the vertical to allow for the stretch in its back guy as it takes the weight of the head of the main derrick.

When raising a heavy derrick it is particularly important to ensure that the head of the auxiliary derrick is kept in the fore-and-aft line of the main derrick and that the latter is raised in its fore-and-aft plane.

Lowering Derricks and Sheers

A derrick (or sheers) is lowered in the reverse manner to that in which it was raised.

Walking a Derrick and Sheers

It may not be convenient to erect a derrick at the place where it is required to work, and it must then first be rigged and raised and then "walked" to the place required. It is not usual on shore to walk a derrick on its shoe; the shoe is first embedded in its proper position and the derrick is then walked over the ground to the shoe. If the ground is insufficiently firm, or the derrick is heavy, it is walked along a pathway of planks, reinforced if necessary by baulks of timber. The foregoing remarks apply also to sheers.

To walk a derrick a spar must be cross-lashed to its foot about 2 ft. 6 in. above the heel, then by lifting on the spar, levering the heel with handspikes, and hauling on the forward foot tackles the derrick is walked towards its shoe. When walking care must be taken to keep the derrick from canting to either side by means of its side guys. If fitted with a strong fore guy walking is facilitated by inclining the derrick backwards to an angle of about 10 degrees, but if the fore guy is only a preventer the derrick must be kept inclined forward at an angle of about 10 degrees. When walking with the derrick inclined forward care must be paid to its angle of inclination, because if this is too small the pull at the derrick head will be insufficient to overhaul the back guy, and if it is too large it will prevent the derrick from walking forward. If the derrick is inclined backwards when being walked a rear heel tackle must be provided.

To walk sheers a spar must be lashed across their feet about 2 ft. 6 in. above the ground, and the ends of the spar should project well beyond each leg. The sheers are then hauled forward by the forward heel tackles, and this is assisted by lifting on the spar and levering the heels with handspikes.

Erecting a Ropeway

Where no suitable trees are available for supporting the overhead span of a ropeway, gyns or sheers must be used. Gyns are preferable to sheers because they are more stable, but sheers may have to be used for long spans with a high ground clearance if suitable spars are not available.

The stresses set up in a span are considerable and in practice can be taken as being up to five or six times the weight of the load. Strong holdfasts must therefore be provided for the span or any back guys, and they should be placed so that the slope of the span or guy from the ground to the head of the support is not steeper than one in four (*i.e.*, on level ground the distance from the holdfast to the feet of the sheers or gyn must not be less than four times their effective length).

The tauter a span the greater will be the stresses imposed on its anchorages and supports, but the easier it will be to haul the load across. On the other hand

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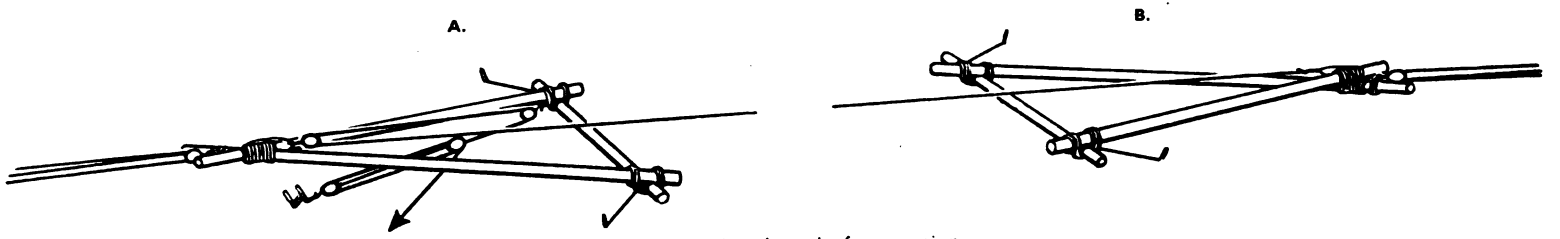
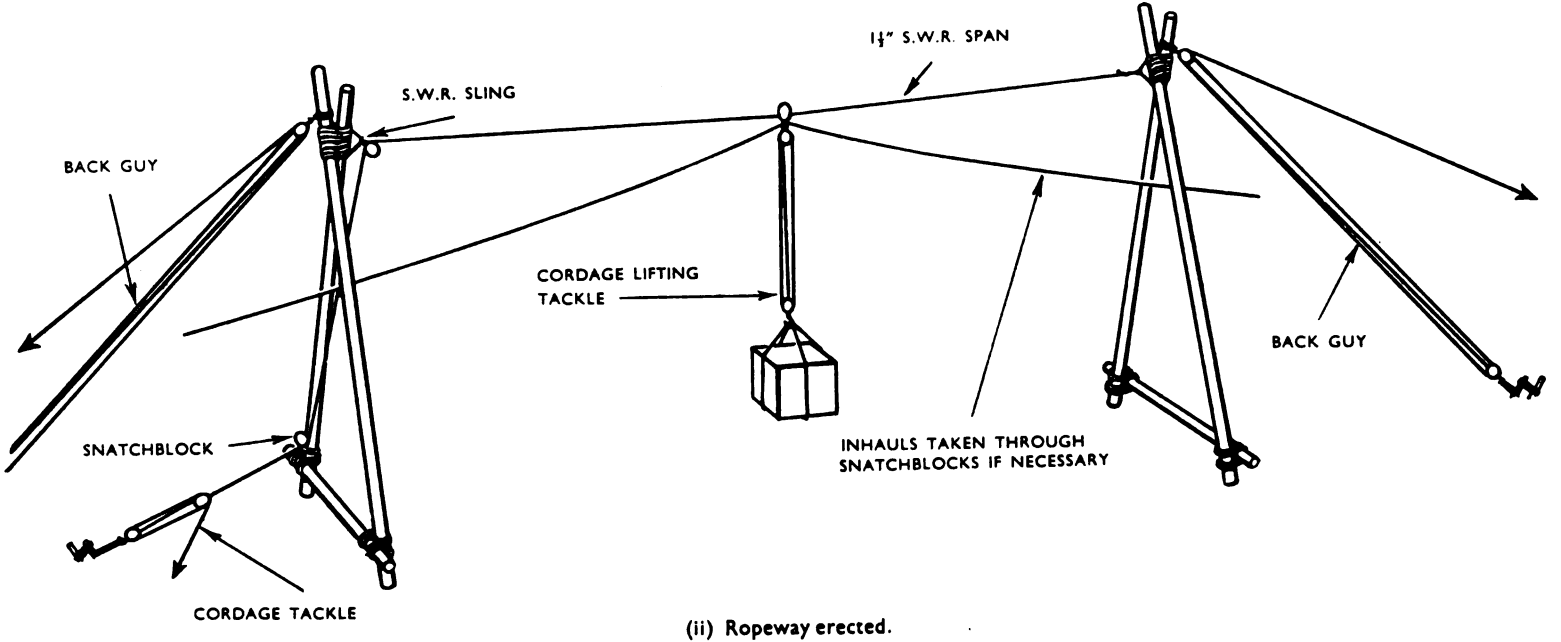


(i) Ropeway rigged ready for erection



(ii) Ropeway erected.

Fig. 61. A light field ropeway

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if the span is too slack, though the stresses in it will be reduced, it will be difficult or impossible to haul the load across, and also the ropeway will tend to become laterally unstable. The practical compromise between these extremes is to adjust the tension in the span to give it a dip of between one fiftieth and one twenty-fifth of its effective length when unloaded, so that when loaded at its centre it will assume a dip of between one twentieth and one tenth of its effective length. For practical purposes the dip in the span when loaded at its centre should not exceed one tenth of its effective length.

The span can be rigged with each end secured to a holdfast and rove through a snatch block slung from the head of each of its supports, or its standing end can be secured to the head of one support, which will then require a back guy. It is usually set up by a tackle on its running end, but for heavy loads its final adjustment must be made by a bottle-screw.

The traveller can be an inverted snatch-block hooked to a light tackle for hoisting the load to the required height before it is traversed, but for heavy loads the traveller should consist of two snatch-blocks lashed to a spar fitted with two lifting tackles, as shown in Fig. 59.

The gyn or sheers must be stepped sufficiently far back from the edge of the gap to allow room to sling the gear on one side and land it on the other. For light loads no leading blocks are required for the traveller inhauls or outhauls, but for heavy loads the inhaul should be led through a leading block at the head of the gyn or sheers but below the span block.

If gyns are used each should be stepped with its prypole towards the gap but slightly to one side of the span, and the inhaul should be led on the opposite side of the prypole to the span. A simple ropeway using a gyn and a tree as supports is shown in Fig. 60.

A method of rigging a ropeway between two sheers in which the span is used to erect both sheers is shown in Fig. 61. The sheers are laid with their heels facing each other and with the standing end of the span secured to the head of the sheers marked B, which are temporarily secured to the ground. The head of the sheers marked A are first raised as high as possible by hand, and then to their full height by hauling on the tackle at the hauling end of the span. The back guy of sheers A is then set up and sheers B are raised in a similar manner.

Provision of Power

Heel tackles and all but the heaviest guys are usually manhandled. The main lifting tackles may be manhandled, but are usually worked by hand- or power-driven winches or capstans, first because the tackles must be worked as smoothly as possible and any jerking be avoided, because it may double the stresses involved, and secondly because of the heavy stress on the hauling part of a main tackle and because the load must be both lifted and held suspended.

Manpower

The force a man can be expected to exert depends chiefly on whether the effort required is momentary or sustained over a period, whether it is made quickly or slowly, and on the manner in which the force is to be applied. It also depends to a certain extent on the number of men employed, the larger the body of men the less will be the individual effort.

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In parties of up to 30 men, and for sustained efforts, each man can be expected to do the following work :—

(i) exert a standing haul of from 56 to 90 lb. (*e.g.*, on the fall of a tackle) ;
(ii) exert a walking haul of from 40 to 50 lb. (*e.g.*, on a drag-rope) ;
(iii) push or pull with a force of from 15 to 20 lb. (*e.g.*, on a capstan bar or a winch handle) ;
(iv) carry from 56 to 90 lb. (*e.g.*, when carrying a spar or a girder).

In parties of up to four men, and for short periods only, each man can be expected to work as follows :—

(i) exert a standing haul of from 120 to 130 lb. (provided he has a good foothold) ;
(ii) exert a stationary push of 100 lb. (provided he has a good foothold) ;
(iii) bear down on a lever with a force of from 70 lb. to his full weight ;
(iv) lift up on a lever at knee-level with a force of 150 lb. ;
(v) carry on his shoulders a weight of 130 lb.

Remarks on Tackles

The blocks of portable tackles used for general purposes must be kept as light as possible, otherwise the tackles would be too cumbersome to handle. This limitation precludes the use of the heavy, specially made blocks of a ship's derrick, which have their sheaves mounted on ball-bearings, and in which friction is reduced to less than 5 per cent of the load. The friction set up in a well-made block of a general purpose tackle maintained in first-class condition will amount to one-tenth of the load for each sheave in the block, but in blocks less well maintained or manufactured this friction will amount to one-eighth of the load. The table on page 227 has therefore been divided into two parts, the left-hand for well-made tackles maintained in first-class condition, and the right-hand for tackles less well made or maintained.

A study of the table will show that up to a certain number the more sheaves there are in a tackle the greater will be the gain in mechanical advantage, but thereafter any additional sheaves will reduce the gain in mechanical advantage because of the friction set up by them. Furthermore, the greater the number of sheaves in a tackle the heavier will be its blocks and the more cumbersome will it be to handle.

For these reasons a three-fold tackle is usually the highest ratio tackle used for general purposes, and in many cases it is better to use a combination of two lesser-ratio tackles than one of high ratio. For example, it will be seen from the table that a gun-tackle clapped on to a runner gives a higher mechanical advantage for a lesser velocity ratio than a three-fold tackle rigged to advantage. When using a combination of tackles, however, the velocity ratio must be taken into account if the fleeting space is limited and speed of operating is of importance. A luff upon luff, for example, provides about twice the mechanical advantage of a three-fold tackle rigged to advantage, but the velocity ratio of the former is more than twice that of the latter.

Leading blocks or rollers to guide the hauling part of the fall of a tackle to a convenient position or clear of an obstruction should be used sparingly, because the friction in each leading block or roller will reduce the mechanical advantage of the tackle by an amount proportional to the angle through which

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the fall is deflected. The friction caused by deflecting the fall through angles of 90 and 45 degrees will amount respectively to roughly a half and a quarter of the friction set up in a sheave of the tackle.

Tackles used for hauling should, whenever possible, be rigged to advantage, *i.e.*, with the hauling part leading from the moving block Hoisting tackles,

VELOCITY RATIOS AND MECHANICAL ADVANTAGES OF TACKLES AND COMBINATIONS OF TACKLES

TYPES AND COMBINATIONS OF TACKLES RIGGED FOR HOISTING AND HAULING	$M = \frac{10V}{10+n}$		$M = \frac{8V}{8+n}$	
	V.R.	M.A.	V.R.	M.A.
Double whip (2 sheaves)—hoisting	2	1·67	2	1·60
Runner (1 sheave)—hauling	2	1·82	2	1·78
Luff tackle (3 sheaves)—hoisting	3	2·30	3	2·18
Spanish Burton (2 sheaves)—hoisting ...	3	2·50	3	2·40
Gun-tackle (2 sheaves)—hauling	3	2·50	3	2·40
Double whip upon double whip (4 sheaves)—hoisting	4	2·79	4	2·56
Two-fold tackle (4 sheaves)—hoisting ...	4	2·86	4	2·67
Luff tackle (3 sheaves)—hauling	4	3·08	4	2·91
Runner upon runner (2 sheaves)—hauling ...	4	3·31	4	3·17
Three-and-two tackle (5 sheaves)—hoisting	5	3·33	5	3·08
Two-fold tackle (4 sheaves)—hauling ...	5	3·57	5	3·33
Three-fold tackle (6 sheaves)—hoisting ...	6	3·75	6	3·43
Luff (disadvantage) upon double whip (5 sheaves)—hoisting ...	6	3·84	6	3·49
Three-and-two tackle (5 sheaves)—hauling	6	4·0	6	3·69
Four-and-three tackle (7 sheaves)—hoisting	7	4·12	7	3·73
Gun-tackle upon double whip (4 sheaves)—hoisting	6	4·17	6	3·84
Three-fold tackle (6 sheaves)—hauling ...	7	4·37	7	4·0
Four-fold tackle (8 sheaves)—hoisting ...	8	4·44	8	4·0
Gun-tackle upon runner (3 sheaves)—hauling	6	4·55	6	4·27
Four-and-three tackle (7 sheaves)—hauling	8	4·70	8	4·27
Four-fold tackle (8 sheaves)—hauling ...	9	5·0	9	4·5
Luff (advantage) upon double whip (5 sheaves) hoisting	8	5·14	8	4·66
Luff upon luff (both disadvantage) ... (6 sheaves)—hoisting	9	5·29	9	4·78
Luff upon runner (4 sheaves)—hauling ...	8	5·61	8	5·16
Gun-tackle upon gun-tackle (4 sheaves)—hauling	9	6·25	9	5·76
Luff (advantage) upon luff (disadvantage) (6 sheaves)—hoisting	12	7·08	12	6·34
Luff upon gun-tackle (5 sheaves)—hauling	12	7·70	12	6·98
Luff upon luff (both advantage) (6 sheaves)—hauling	16	9·49	16	8·47

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however, must be rigged to disadvantage, unless a combination is used, because of the necessity of leading the hauling part downwards from the upper, or standing, block.

The blocks of a tackle are usually stronger than its fall, and in tackles rove with cordage falls, and using a factor of safety of six, the safe working load of a tackle is that of its fall.

If, however, the factor of safety is reduced, then the safe working load of the tackle may depend on the strength of its standing block. In tackles rove with wire rope falls their safe working loads may be determined not by the safe working load of the fall, but by the strength of their standing blocks, even when using a factor of safety of six. If, therefore, there is any doubt about the safe working load of a tackle the strength of its blocks should be compared with the safe working load of the fall, and the lower amount be taken as the safe working load.

Tackles and combinations of tackles for hauling are assumed to be rigged to advantage. Tackles and combinations of tackles for hoisting are assumed to be rigged to disadvantage, except where stated otherwise.

Hand Winches

These are usually used in preference to crab capstans when power-worked machines are not available. A hand winch is designated by the maximum pull which can be applied by it, the winches usually provided being of 1, 3, 5, 8 and 10 tons capacity ; in practice, however, only about seven-tenths of its maximum pull can be applied by the men working a winch. The winch is provided with a crank handle on each side, and they should be shipped at an angle of 90 degrees to each other to avoid dead-centres ; the number of men who can work on each handle varies from two to four, depending on the size of the winch. To prevent a winch up-ending when under load it must be bolted to wooden bearers which should project far enough in front of the winch to ensure that the up-ending moment is balanced by the weight of the winch on the rear end of the bearers. The bearers themselves should be braced together and secured from moving by pickets driven in in front of them, and their rear ends should be secured to a holdfast. The following formula gives the length of the bearers required for a particular pull on the winch-rope :—

$$L = \frac{PH}{W},$$

where :—

L is the minimum distance in feet from the forward end of the bearer to the centre of the winch ;

P is the pull in the winch-rope ;

H is the height in feet of the bottom of the drum above the bearer ;

W is the weight of the winch in the same units as P.

The weight of a winch can be taken roughly as being one-third of its maximum pull.

The winch-rope must be led on to the bottom of the drum to reduce its

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up-ending moment to a minimum. The rope capacity of a winch drum is given by the following formula :—

$$L = \frac{2{\cdot}5\ bf\ (f + d)}{c^2},$$

where :—

L is the length of the winch-rope in feet ;
b is the length of the drum in inches ;
d is the diameter of the drum in inches ;
f is the depth of the flange of the drum in inches ;
c is the circumference of the rope in inches.

Spars (*see* also table on p. 232)

Timber for spars is designated generally as " selected " and " unselected." By selected is meant all new and well-seasoned timber, and also little-used old timber which has been kept dry and appears to be sound. All other timber must be considered as " unselected." The strength of unselected timber should be taken as being half that of selected timber.

Selected timber is grouped according to the compressive strength of the type of wood used : Group I timber includes oak, teak, Douglas fir and Oregon pine ; Group II includes Baltic fir, northern pine, Norway fir, elm and deodar ; and Group III includes white pine, white deal and red cedar. Timber of Group I is about one-fifth stronger than that of Group II, which in turn is about one-fifth stronger than that of Group III. Group I timber is used for the masts and derricks of a ship when they are of wood and also for the shoes of extempore derricks ; Group II timber is used for the spars of extempore sheers, derricks and gyns ; Group III timber is unreliable and is used only for planks and skidding.

The strength of a spar varies with the ratio between its diameter and its effective length. Size for size (*i.e.*, diameter for breadth) a spar of circular cross-section is about three-fifths the strength of a spar of square cross-section. An overloaded spar will usually break at the middle of its length. A spar can be strengthened by fishing approximately the central third of its effective length.

Precautions

Only gear in first-class condition should be used for work of an extempore nature, and with such gear a factor of safety of six is usually allowed. It may, however, be necessary to reduce this factor of safety to provide gear which is light enough to be handled with the means available, but the factor of safety should not be reduced to less than three (except for timber for which a factor of safety of two is usually used).

The hauling ends of all tackles should be led to positions where the men working them will be clear of danger should the spars collapse or fall over.

Sheers and derricks should not be heeled beyond an angle of 20 degrees with the vertical unless the back guy is particularly strong and secure, and leads from the head at an angle of at least 70 degrees to the spars when they are heeled.

One hand should be detailed to watch each holdfast when hoisting or lowering a load. If the back guy holdfast starts to give, lower the load and at the same time haul it towards the foot and haul in on the back guy ; this will ease the stress in the back guy.

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All tackles should be worked as smoothly as possible and any jerking be avoided. If, after hoisting, a load has to be left suspended the fall should be eased back slightly to equalise the stresses between its running parts.

When a load is lowered with the derrick or sheers nearly vertical, unless the back guy is checked as the load nears the ground, its weight will tend to haul the derrick or sheers over backwards when the load touches the ground.

When hoisting a load the derrick or sheers should never be topped up while the main tackle is being worked, because this puts excessive stresses on the derrick or sheers.

Data and Formulæ for Estimating Stresses in Derricks, Sheers and their Rigging

It is emphasised that many of the formulæ given below are for rough estimates only, and that where gear is liable to be stressed to the full extent of its safe limit the stresses must be accurately calculated by means of a triangle or polygon of forces and by reference to the rope tables in Volume II of this manual.

CORDAGE (manila and sisal)

Weight in lb. per fathom $= 0{\cdot}19C^2$;

Safe working load in cwt :—

with a factor of safety of 6 $= C^2$;

with a factor of safety of 3 $= 2C^2$,

where C is the circumference of the rope in inches.

Safe working load of a lashing or a strop in cwt. $= nC^2$,

where n is the number of turns in the lashing, or half the number of parts in the strop, and C is the circumference of the rope in inches. This includes allowances for bad nips and unequal distribution of stress among the parts.

WIRE ROPE

Weight in lb. per fathom $= C^2$,

where C is the circumference of the rope in inches.

Breaking stress in tons :—

for S.W.R. $= 2{\cdot}5C^2$;

for F.S.W.R. under $4\frac{1}{2}$ in. $= 2C^2$;

for F.S.W.R. $4\frac{1}{2}$ in. and over $= 2{\cdot}25C^2$;

for E.S.F.S.W.R. $= 3{\cdot}6C^2$,

where C is the circumference of the rope in inches.

Minimum factors of safety for wire ropes :—

spans and guys = 3 to 4;

lashings and strops = 4 to 5;

slings and main tackle falls = 6 to 8.

Safe working load of a lashing or a strop in cwt. $= 7nC^2$,

where n is the number of turns in the lashing or half the number of parts in the strop, and C is the circumference of the rope in inches. This includes allowances for bad nips and unequal distribution of stresses among parts.

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SLINGS

Safe working load in cwt. = nP cos A,

where :—

P is the safe working load of the rope in cwt. ;

n is the number of legs in the sling ;

A is the angle between the leg of the sling and the vertical.

If the sling is subjected to bad nips, either on the hook or on the load, the safe working load should be taken as two-thirds that given by the formula.

CHAIN (wrought-iron)

Safe working load in tons :—

for studded-link chain = $9d^2$;

for short open-link chain = $6d^2$;

for long open-link chain = $4d^2$.

Weight in lb. per fathom = 59 to $64d^2$,

where d is the diameter of the iron in inches.

TACKLES

$$\text{Safe working load in cwt.} = \frac{PV}{1 + fn'}$$

where :—

P is the safe working load of the fall in cwt. ;

V is the velocity ratio of the tackle ;

f is the coefficient of friction which may vary between $\frac{1}{5}$ and $\frac{1}{10}$ according to the condition of the tackles—usually $\frac{1}{10}$;

n is the number of sheaves in the tackle including any leading blocks.

Caution.—The safe working load so obtained is based on the safe working load of the fall, and in some cases it may exceed the safe working load of the blocks in the tackle, particularly when the factor of safety for the fall has been reduced to below 6.

$$\text{Pull on hauling part in cwt.} = \frac{W(1 + fn)}{V},$$

where :—

W is the weight to be hoisted in cwt. ;

V is the velocity ratio of the tackle ;

f is the coefficient of friction ;

n is the number of sheaves in the system.

Pull on anchorage of standing block :—

of hoisting tackles = W + P ;

of hauling tackles = W − P,

where :—

W is the weight hoisted ;

P is the pull on the hauling part of the tackle.

RINGS, HOOKS AND SHACKLES

$$\text{Safe working load of a wrought-iron ring in tons} = \frac{9d^3}{D},$$

where :—

d is the diameter of the iron ;

D is the mean diameter of the ring.

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SAFE LOADS FOR SPARS OF VARIOUS DIMENSIONS FOR USE WITH DERRICKS, SHEERS AND GYNS

(Selected Timber of Group II)

MEAN DIAMETER OF SPAR IN INCHES	10 ft.	15 ft.	20 ft.	25 ft.	30 ft.	35 ft.	40 ft.	45 ft.	50 ft.	55 ft.	60 ft.	65 ft.	70 ft.	75 ft.	SIZE OF EQUIVALENT SQUARE BAULK IN INCHES
6	3·4	1·8	0·9	0·4	—	—	—	—	—	—	—	—	—	—	5
7	5·4	2·6	1·9	1·0	0·4	—	—	—	—	—	—	—	—	—	5·8
8	8·2	5·1	3·3	2·0	1·1	0·4	—	—	—	—	—	—	—	—	6·7
9	11·8	7·6	5·1	3·4	2·1	1·2	0·5	—	—	—	—	—	—	—	7·5
10	15·9	10·4	7·3	5·1	3·5	2·3	1·3	0·5	—	—	—	—	—	—	8·3
11	20·8	14·0	10·3	7·2	5·3	3·6	2·4	1·3	0·4	—	—	—	—	—	9·2
12	26·4	18·6	13·5	10·0	7·4	5·4	3·8	2·5	1·4	0·5	—	—	—	—	10·0
13	32·9	22·9	17·6	12·9	10·1	7·4	5·6	3·9	2·7	1·5	0·6	—	—	—	10·8
14	40·8	29·9	21·5	16·6	12·9	10·0	7·7	5·8	4·2	2·6	1·5	0·5	—	—	11·7
15	46·7	36·3	27·4	21·1	16·4	12·8	10·4	7·9	5·9	4·2	2·8	1·7	0·6	—	12·5
16	56·9	41·3	32·9	25·2	20·5	16·0	13·1	10·0	8·0	5·9	4·4	2·8	1·7	0·5	13·3

Note: These values must be halved if unselected timber is used.

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Safe working load of a hook in tons $= d^2$,
where d is the diameter of the metal at the *back* of the hook.

Safe working load of a straight shackle $= 4d^2$;
Safe working load of a bow shackle $= 2{\cdot}5d^2$,
where d is the diameter of the metal at the *crown*.

HOLDFASTS

Pickets of ash 5 ft. long and 3 ft. diameter driven 3 ft. into good ground will hold a safe stress of :—

singly	...7 cwt.
one-and-one combination	...14 cwt.
two-and-one combination	...1 ton
three-two-and-one combination	...2 tons

allowing a factor of safety of 3.

Baulk and pickets.—Allow a safe holding stress of 6 cwt. for each picket up to the safe sheer stress of the baulk (see below for working stresses of timber).

Buried baulk.—The table below gives the safe resistance in pounds for each square foot of the face of the baulk when buried in good loam earth.

MEAN DEPTH OF BAULK BELOW SURFACE, IN FEET	SAFE RESISTANCE IN LB. PER SQ. FT. OF FACE WHEN SLOPE OF STROP IS :—			
	ONE IN ONE	ONE IN TWO	ONE IN THREE	ONE IN FOUR
1	110	150	160	175
1½	250	320	360	390
2	410	580	650	700
3	950	1,300	1,450	1,500
4	1,750	2,200	2,600	2,700
5	2,800	3,600	4,000	4,100
6	3,800	5,100	5,800	6,000
7	5,100	7,000	8,000	8,400

TIMBER

Spars for derricks, sheers and gyns (selected timber of Group II).—The table on page 232 gives the safe load in tons on spars of various sizes and lengths. The table is based on the formula :—

$$p = \tfrac{1}{3} f \frac{70 - \frac{l}{d}}{10 + \frac{l}{d}},$$

where :—
p is the safe load in tons/in^2;
f is the safe compressive strength in tons/in^2;
l is the length of the strut in inches;
d is the least diameter of the strut in inches.

The value of f has been taken as $\frac{2}{3}$ tons/in^2 for Group II selected timber, and the values obtained from the formula have been halved to allow for the end of the spar being free, eccentric loading on lifting tackle and guys, and stresses due to jerks in the tackles. If unselected timber is used the figures in the table must be halved.

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Safe thrust on spars can be obtained from the formula :—

$$T = \frac{VR^4}{L^2},$$

where :—

T is the safe thrust in tons ;
R is the radius of the spar in inches ;
L is the effective length of the spar in feet ;
V is a coefficient depending on the type of wood, which for oak is 14, for Oregon pine is 12, for Baltic fir is 10, and for larch is 8.

Baulks for holdfasts.—The safe working load of a selected baulk of fir is given by the formula :—

$$W = \frac{bd^2}{L},$$

where :—

W is the safe working load in tons ;
b is the breadth of the baulk in inches ;
d is the depth of the baulk in inches ;
L is the length between supports in inches.

For selected timber other than fir the values obtained by the formula should be multiplied by a factor, which, for African oak is 2, for other oak is 1·5, for pitch-pine is 1·3, and for elm is 0·6.

If unselected timber is used all values should be halved.

The breaking load is twice the safe working load.

Weight per cubic foot of various types of timber is given in the table below

TYPE OF TIMBER	WEIGHT PER CU. FT. IN LB.	TYPE OF TIMBER	WEIGHT PER CU. FT. IN LB.
Ash and *Beech* ...	48	*Oak :*	
		African ...	62
Deal :		American white	49
Christiania ...	43	American red...	53
English	29	English ...	52
Scotch	31		
Elm :		*Pine :*	
Canadian ...	45	Scotch... ...	41
English	35	pitch	38
		Oregon ...	37
Fir :		Norwegian and	
Douglas... ...	38	red	34
larch	32	yellow	32
spruce	35	white	30
Greenheart... ...	71	*Teak :*	
		African ...	60
		Burmese ...	54
		Indian... ...	46

Note.—The weight of timber gives an indication of its strength, the greater the weight per cubic foot the stronger is the timber.

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APPROXIMATE STRESSES IN DERRICKS, SHEERS AND GYNS

The table below shows the approximate stresses in the different parts of derricks, sheers and gyns in terms of the load (W) to be lifted. It is assumed that the main lifting tackles are three-fold purchases, and that the gear is rigged and worked in the normal manner, *i.e.*, that :—

the splay of sheers is one-third of their effective length ;
the splay of a gyn is one-half of its effective length ;
a derrick, or sheers, is not heeled beyond 20 degrees from the vertical ;
the weight is not picked up at a greater distance from the foot than one third of the effective length ;
the guys are led at a slope not steeper than one in two.

Main tackle :		*Standing derrick spar*	1·8 W
running part down leg	0·3 W	*Sheers spars :*	
hauling part	0·33W	leg with leading block	1·1 W
size of fall (f.s.6)	$\sqrt{5}$ W	other leg	0·75W
Back guy and main side guys :		with two main tackles, each leg	0·9 W
standing derrick	0·55W	*Gyn spars :*	
sheers	0·6 W	leg with leading block	0·6 W
Preventer guys	0·3 W	other legs	0·4 W
Heel tackles :		*Splay tackles :*	
standing derrick	0·55W	sheers	0·5 W
sheers, each	0·3 W	gyn	0·3 W

SPANS

The theoretical tension in a span between supports at the same level can be calculated from the formula :—

$$T = \frac{WL}{4D},$$

where :—

T is the tension in the span ;
W is the total weight of the load, including the traveller and slings ;
L is the distance between the supports of the span ;
D is the dip of the span in the same units as L.

If D is expressed in terms of L then :—

when D is $\frac{1}{20}$ of L, T = 5W, and
when D is $\frac{1}{10}$ of L, T = 2·5W.

This formula, however, does not take into account the weight of the span which must be considered when the span is long and the load heavy. In the table below the weight of the span, where appreciable, has been taken into account ; it is based on a factor of safety of 4, with a dip in the span of one-twentieth of its length when the load is at its centre. The difference in level between the supports of the span should not be more than one twenty-fifth of its length. The load must include the weight of slings and traveller, and an allowance of 10 per cent. must be made for impact loading and any wind.

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SIZE OF F.S.W.R.	TENSION IN SPAN	TOTAL LOAD ON SPANS OF			
		200 FT.	300 FT.	400 FT.	500 FT.
in.	*ton*	*cwt.*	*cwt.*	*cwt.*	*cwt.*
1	0·5	2	1·9	1·8	1·6
1½	1·0	4	3·8	3·6	3·2
2	2·8	10	9·5	9·0	8·0
2½	4·2	16	15·2	14·4	12·8
3	6·4	22	20·9	19·8	17·6

SLEIGHS

A sleigh provides a useful means of moving a heavy load when wheeled transport cannot be used or is not available.

It consists of a wooden structure drawn over rollers of steel, or hardwood such as oak or elm. These rollers must be tended continually as the sleigh advances, and unless the ground is very hard and smooth they should run on a roadway of planks laid down before them. If the roadway is slippery it should be sanded to ensure the rollers " biting." A common sleigh is from six to ten feet long and some three feet wide. The centre of gravity of the load is arranged to be as nearly as possible over the centre of the sleigh, and the whole is pulled along by a sling attached to the load itself, never to the sleigh.

Building a Sleigh

The simplest type of sleigh consists of two thick planks lashed side by side with 1½ in. cordage and laid on rollers, and it is called a "plank sleigh" (see Fig. 62). The lashing is tautened by wedges and the load lowered on to chocks placed on the planks.

A suitable plank sleigh for loads of up to five tons would be made of two fir planks, 10 ft. × 17 in. × 3 in. running on 6-in. diameter elm rollers. For heavier loads stronger planks must be used, or the planks can be arranged in two or more layers; plank sleighs can be used to take loads of up to ten tons. If corners do not have to be negotiated by the sleigh the lashing can be omitted.

An alternative type which can be used for heavier loads is known as the " skid sleigh," and one suitable for a load of ten tons is described below and illustrated in Fig. 62.

Two fir " skids " 14 ft. × 8 in. × 8 in. are laid on three 10-in. diameter oak rollers to form the main bearing surface (skids consist of rectangular lengths of timber and can be of various dimensions). Across the skids are laid two lengths of oak, 3 ft. × 6 in. × 5 in., called " transoms," which are fitted with chocks to support the load. The hard oak of the transoms will bite into the soft fir of the skids and so help to bind them together, but for added security they can be bolted together or secured by staples.

Sleighs can be built for heavier loads by increasing the size and number of planks, transoms, skids and rollers.

In building a sleigh to carry a certain load the working load for each component part (except the rollers) can be calculated from the formula $W = \frac{KBD^2}{L}$,

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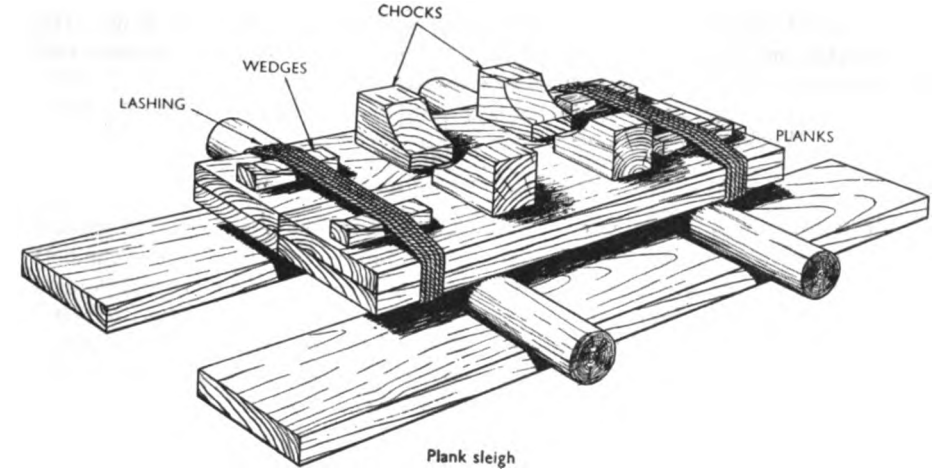
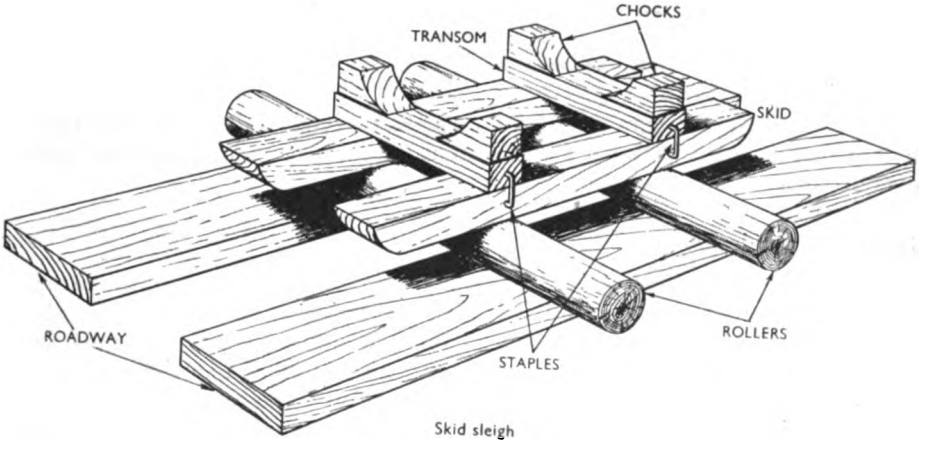


Plank sleigh



Skid sleigh

Fig. 62. Types of sleighs

where W is the working load in tons ; B is the breadth in inches ; D is the depth in inches ; L is the length in inches between supports ; and where K is 1 for fir, 2 for African oak, 1·5 for oak or pitch-pine, and 0·6 for elm. If unseasoned or unselected timber is used the values given for K should be halved.

If in doubt as to what value to use for L when calculating the strength of the platform or skids of a sleigh, choose the greatest expected distance between the rollers, or the distance between the transoms, whichever is the greater.

Examples :

(i) A sleigh consists of two fir planks each 10 ft. × 17 in. × 3 in. The greatest expected distance between the rollers is 5 feet. What is the working load ?

$$\text{Working load of each plank} = \frac{17 \times 9}{60} = 2{\cdot}55 \text{ tons.}$$

$\therefore$ Working load of sleigh = 5·1 tons.

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(ii) A sleigh is built of two fir skids each 14 ft. × 8 in. × 8 in. The greatest distance between the rollers is 7 ft. and the distance between the transoms is 8 ft. What is the working load ?

$$\text{Working load of one skid} = \frac{8 \times 64}{96} = 5{\cdot}35 \text{ tons.}$$

$$\therefore \text{ Working load of sleigh} = 10{\cdot}7 \text{ tons.}$$

Rollers commonly used vary in diameter from six to ten inches. The smaller the rollers employed the easier they are to manhandle, but the choice of the best size and number to use is largely a matter of experience. As a general guide a 6-in. diameter elm roller will work efficiently when supporting two tons for every foot of its bearing length, and a 10-in. diameter elm roller will take 2½ tons; oak rollers will take double these weights. It is usual to employ 6-in. rollers for weights up to 7½ tons and 10-in. rollers for heavier work.

Example :

A sleigh with three 9 in. × 9 in. fir skids is supported on three 10-in. diameter elm rollers ; what weight will the rollers support ?

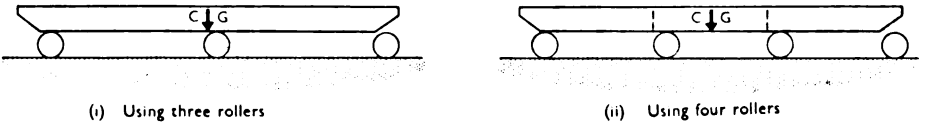
$$\text{Bearing length of each roller} = 3 \times 9 \text{ in.} = 27 \text{ in.}$$

$$\therefore W = 3 \times \frac{27}{12} \times 2{\cdot}5 = 16{\cdot}9 \text{ tons.}$$

In general three rollers are used for sleighs carrying loads of up to 2 tons, four rollers for loads between 2 and 10 tons, and five or more rollers for loads over 10 tons.

Handling a Sleigh

To manœuvre a loaded sleigh into any required position requires correct management of the rollers. Initially these are arranged so as to support the sleigh at regular intervals, as shown in Fig. 63, and these intervals must be maintained as the sleigh advances. This is done by feeding in a roller in front of the sleigh immediately one comes clear behind it ; the roller thus fed in is said to " take." The correct positions of the remaining rollers when a new one should take are marked on the sides of the sleigh in chalk ; the position of the rollers can therefore be checked at frequent intervals and they can be adjusted if necessary by means of heavy mauls. The centre of gravity of the sleigh and its load must also be marked, because this determines the positions of the rollers when the sleigh is manœuvred. Scotches or wooden wedges must be provided for placing under the rollers when it is required to hold the sleigh temporarily in position, and the rollers should be tended continually with handspikes.



(i) Using three rollers (ii) Using four rollers

Fig. 63. Positions of rollers relative to a sleigh

When using three rollers the sleigh is divided into two equal parts and the rollers are applied as shown in Fig. 63 (i). When using four rollers the sleigh is divided into three equal parts and the rollers are applied as shown in Fig. 63 (ii).

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To manœuvre a sleigh over or around obstacles it is often necessary to arrange that a certain point on the sleigh (*e.g.*, the centre of gravity) and a roller will arrive together at an exact position ahead on the roadway. This is done by making use of the principle that the sleigh travels twice as fast as the rollers.

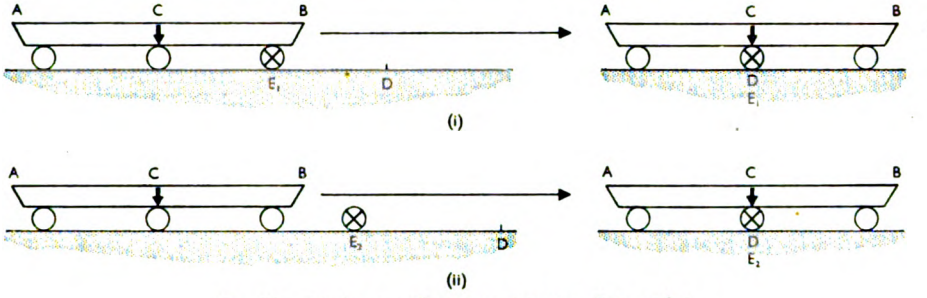

Fig. 64. Placing a roller to arrive at a given point

In Fig. 64, ACB is a sleigh and D a point on the roadway. It is required to place a roller X so that it and point C will arrive together at D. The position, E, at which to place the roller X is determined as follows :—

if CB is greater than BD the roller must be placed at E_1, so that $E_1D = \frac{1}{2}CD$, but if CB is less than BD the roller must be placed at E_2, so that $E_2D = CB$.

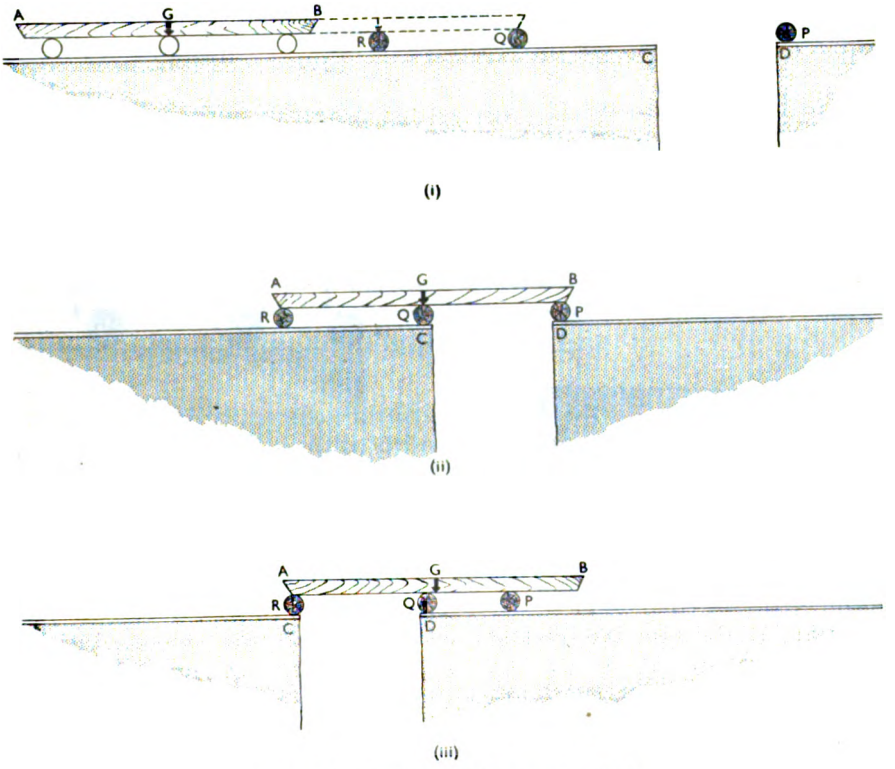

Fig. 65. Passing a sleigh across a ditch

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This principle is also used when hauling a sleigh over a ditch, and the procedure is described below and illustrated in Fig. 65. The width of the ditch must be at least 3 inches less than half the length of the sleigh.

In Fig. 65 (i), AB is a sleigh of which G is the centre of gravity. It is to be passed over the ditch CD by means of the rollers P, Q and R.

Roller P is placed at point D, on the far side of the ditch ; rollers Q and R are placed so that the distances CQ = BG, and CR = BA.

From Fig. 65 (ii), it will be seen that just before the centre of gravity G and the roller Q reach the point C, roller P will take the head of the sleigh B, and the sleigh will remain in equilibrium.

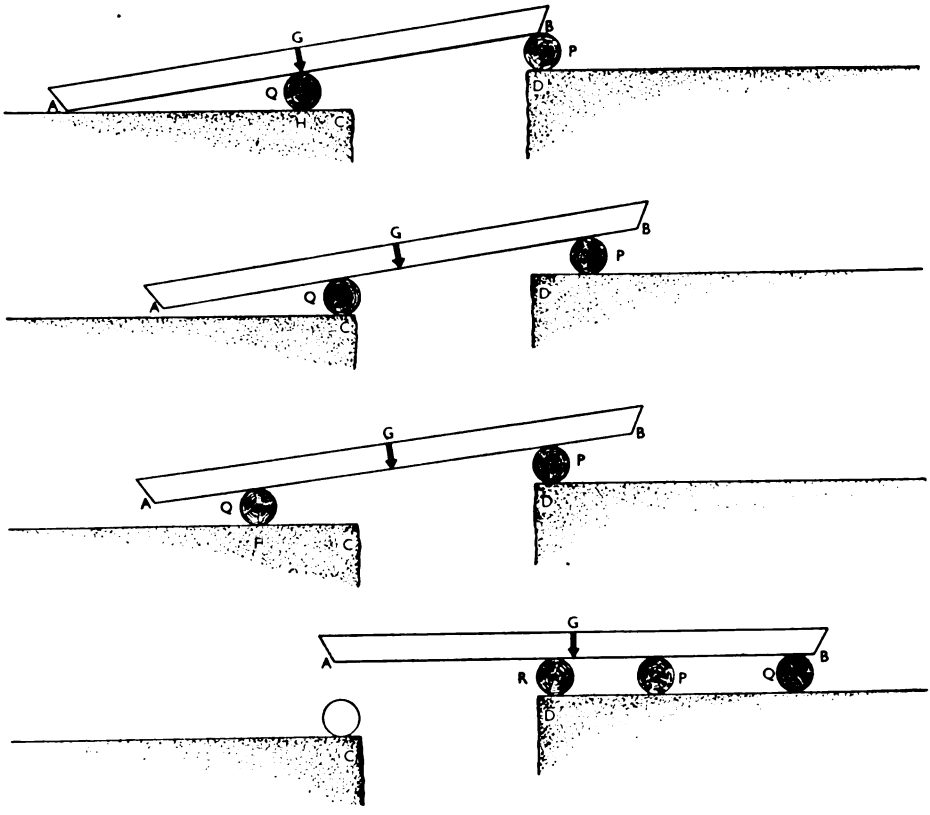

Fig. 66. Passing a sleigh across a ditch having one side higher than the other

As the sleigh moves forward (see Fig. 65 (iii)), and just before the point A leaves the roller R, the roller Q is inserted behind the centre of gravity G, thus maintaining the equilibrium of the sleigh.

If the sides of the ditch differ in level by not more than the diameter of the rollers, it can still be negotiated, but the procedure must be modified slightly as described below and illustrated in Fig. 66.

Roller P is placed at D as before, and a position H is chosen so that DH = BG. Arrangements must then be made for roller Q and point G to arrive together at H.

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When the roller Q reaches the edge of the ditch C, each end of the sleigh is lifted in turn to allow roller P to be run back to D, and for roller Q to be run back to F; CF being half AC. Before A leaves roller Q a new roller R is inserted behind G, and roller Q is moved to the front of the sleigh.

The situation of the rollers at the various stages of negotiating a ramp are illustrated in Fig. 67. Of these stages, (ii) and (iv) require particular notice. At (ii) it will be seen that the sleigh is not supported at its centre and it is therefore necessary to insert rollers at each end at frequent intervals, or the end concerned will drop. Just before the sleigh becomes parallel with the ramp a roller must be placed so as to take behind the centre of gravity.

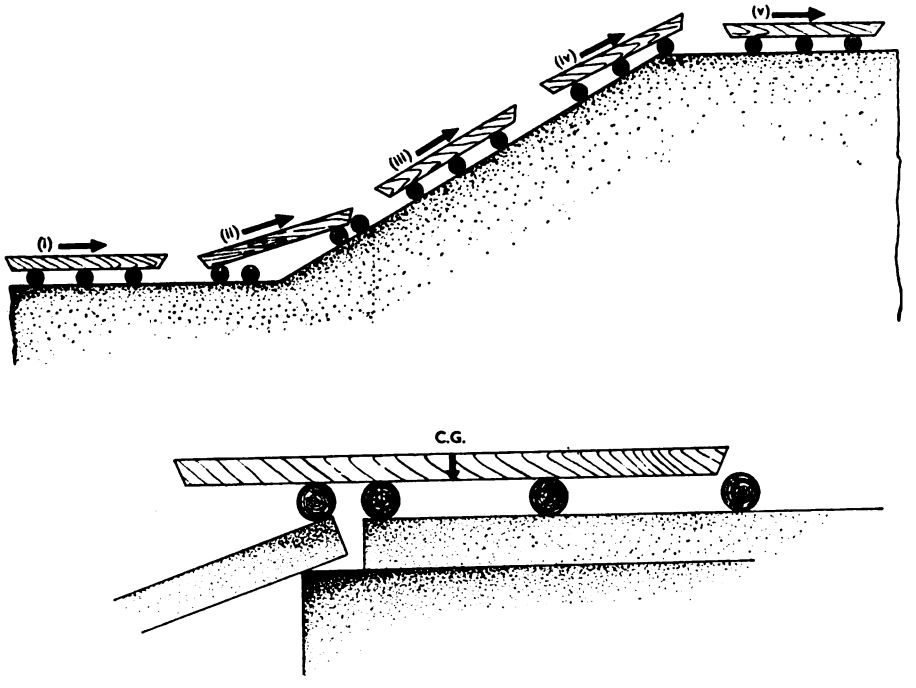

Fig. 67. Hauling a sleigh up a ramp

It is advisable not to allow a roller and the centre of gravity to reach the top of the ramp at the same time, and a roller should be placed so that the sleigh will dip at a convenient distance short of the top on to a roller placed at the edge (stage (iv)). It should be borne in mind that the pull of the tackle will cause the sleigh to dip before the centre of gravity reaches the roller.

The procedure for travelling down a slope is the reverse of that described above.

Should there be a gap between the top of the ramp and the upper roadway, as shown in the lower sketch in Fig. 67, it is important that the ramp should be an inch or so higher than the roadway. This will enable a roller to be inserted behind the centre of gravity of the sleigh before the rear roller falls into the gap. Similarly, if the sleigh is to be taken down the slope, the top of the ramp should be just below the level of the upper roadway.

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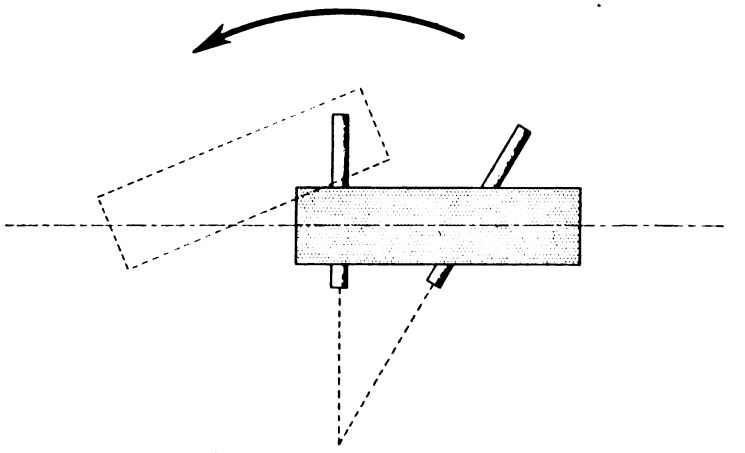
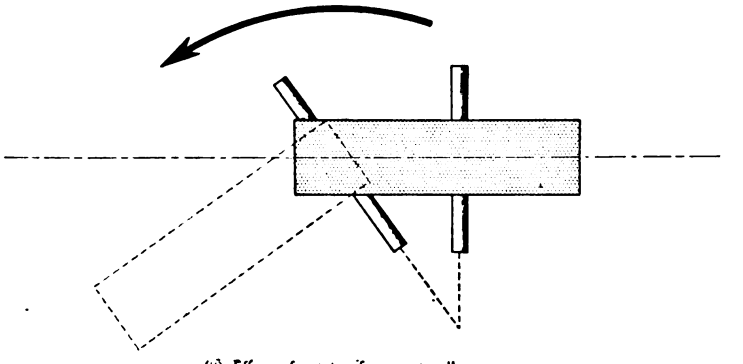
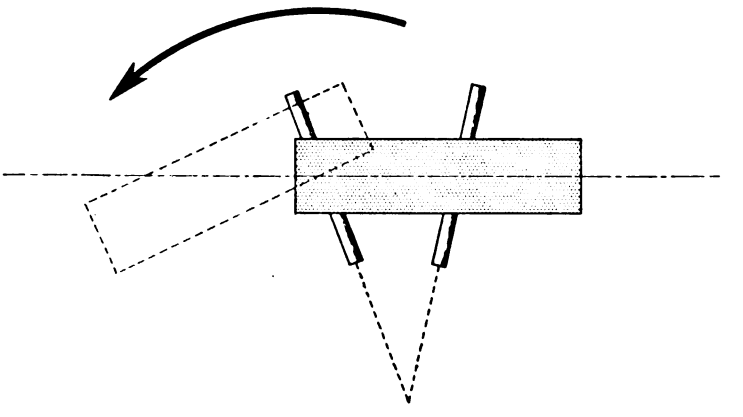


(i) Effect of cutting the rear roller



(ii) Effect of cutting foremost roller



(iii) Effect of cutting both rollers equally

Fig. 68. Effects of cutting one or both rollers when hauling a sleigh round a curve

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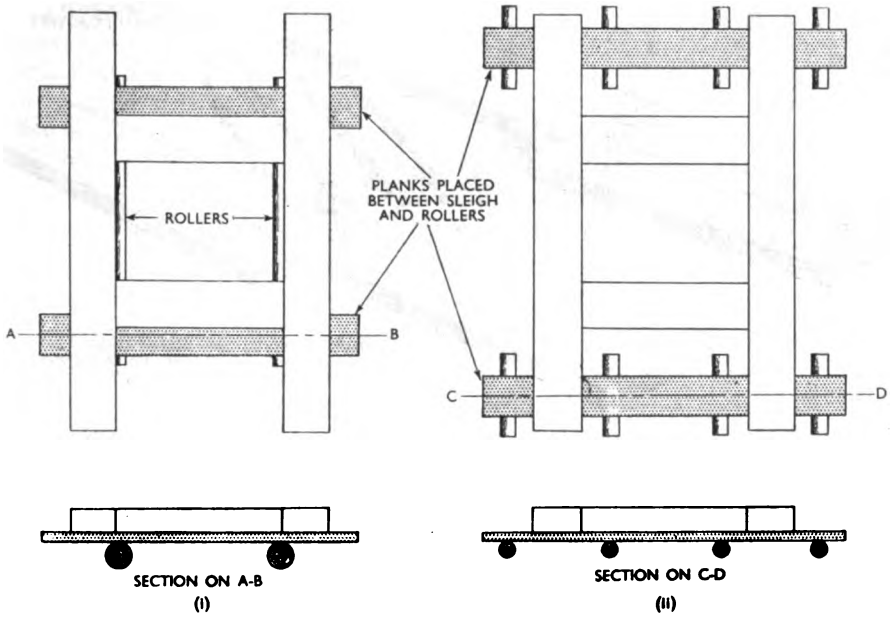
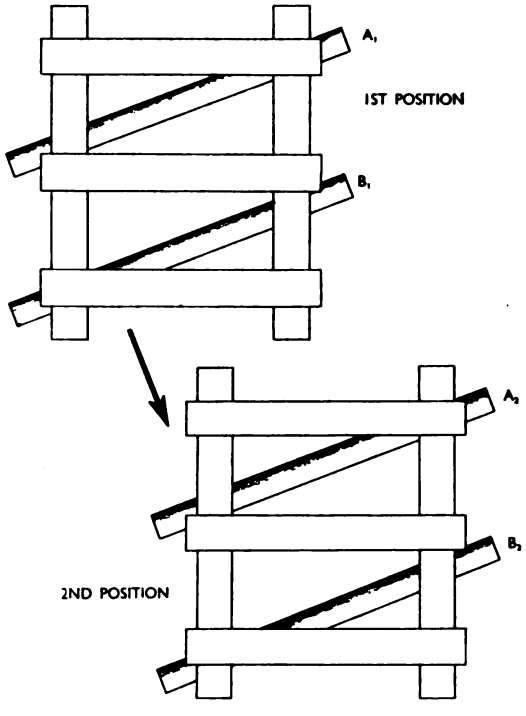


Moving a sleigh squarely to a flank
(I) On its own rollers
(II) On small subsidiary rollers



Moving a sleigh obliquely to a flank

Fig. 69. Moving a sleigh to a flank

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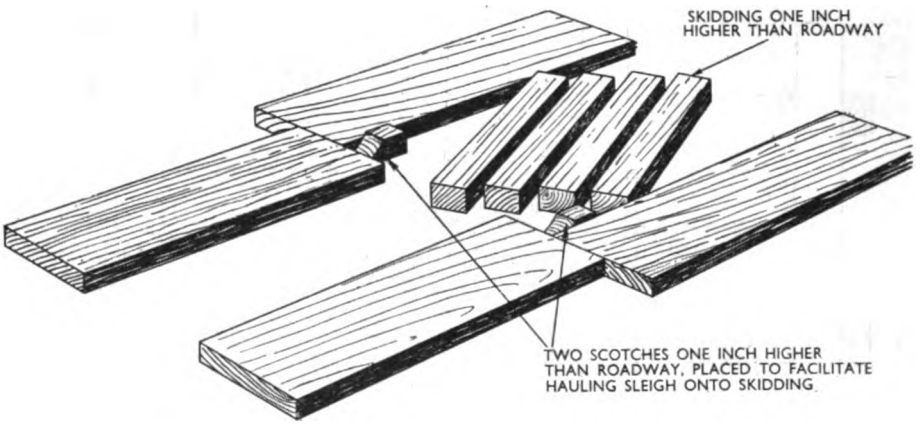
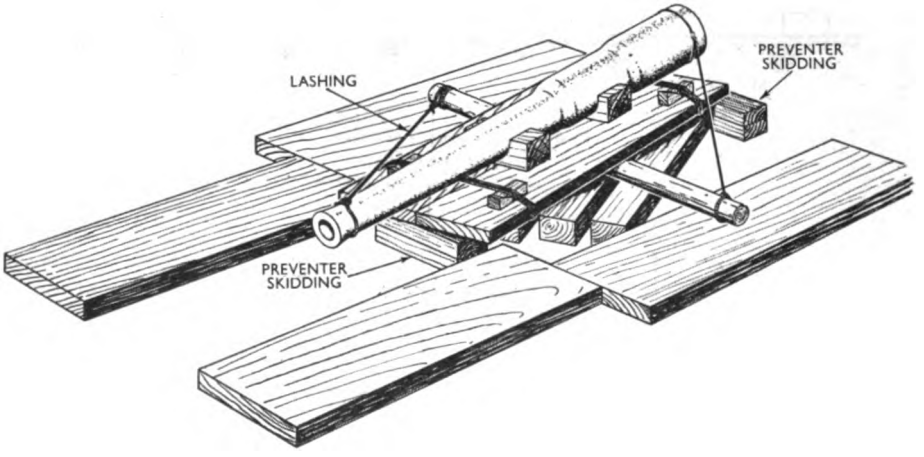

SKIDDING ONE INCH HIGHER THAN ROADWAY
TWO SCOTCHES ONE INCH HIGHER THAN ROADWAY, PLACED TO FACILITATE HAULING SLEIGH ONTO SKIDDING

(i) Roadway and skidding prepared for slewing (anti-clockwise).



(ii) Ready to slew

Fig. 70. Slewing a sleigh

When hauling a sleigh up a ramp the rollers should always be chocked with scotches behind them in case the hauling tackles or their strops or holdfasts give way. It is always better to use two tackles than one for the following reasons :—

(i) if a tackle, or its strop, or holdfast parts or gives way the other tackle will hold the sleigh ;

(ii) one tackle can hold the sleigh while the other is fleeted ;

(iii) two tackles will haul at twice the speed of one tackle of double the power.

Hauling a Sleigh round a Curve

A sleigh can be made to travel round a curve by inclining the rollers to each other as in Fig. 68, this is known as " cutting " the rollers.

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The rollers are cut so that their axes intersect at a certain definite point which must be estimated by eye. As the rollers turn, the sleigh moves in a circle round this point, and at the same time it is displaced laterally by the travel of the rollers over the ground. The combined effect of these two movements is shown in the illustration which also shows the results of cutting one or both rollers.

When passing a sleigh round a curve it will be necessary to cut and recut the rollers at frequent intervals, so as to keep the sleigh fairly on the roadway.

Moving a Sleigh to a Flank

A sleigh can be moved to a flank by arranging the rollers as shown in Fig. 69.

Slewing a Sleigh

A sleigh can be slewed on its centre or made to pivot round one end.

To slew it on its centre, arrangements must be made for the centre of gravity and a roller to arrive together at the point where it is desired to slew. The remaining rollers are then cleared away, and " preventer skidding " (*i.e.*, odd lengths of wood) a few inches lower than the rollers is placed beneath each end in case the sleigh should dip whilst being slewed. The sleigh can then be forced round in the required direction while pivoting on the roller.

It may be more convenient, however, for the roller to pivot with the sleigh, and this can be done by running the sleigh on to skidding placed in the centre of the roadway, as shown in Fig. 70.

The skidding should be an inch higher than the roadway, and inclined towards the direction in which it is intended to slew so that it will make a broad angle with the roller throughout the operation. The sleigh is then run up over oak scotches on to the skidding, preventer skidding is placed under the front and rear ends of the sleigh, and the ends of the roller are lashed to the front and rear ends of the load, as shown in Fig. 70 (ii).

A sleigh can be pivoted round one end by supporting that end on a roller cut at an angle to the sleigh and supporting the other end on a plank running on four small rollers, as shown in Fig. 71.

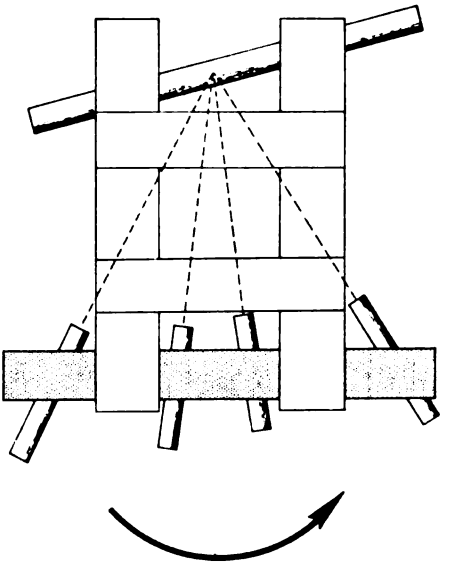

Fig. 71. Pivoting a sleigh round one end

Pull Required to Haul a Sleigh

The pull required to start a sleigh on the level when mounted on elm rollers is roughly one-sixteenth of the weight, and to keep it moving the pull is roughly one-twentieth of the

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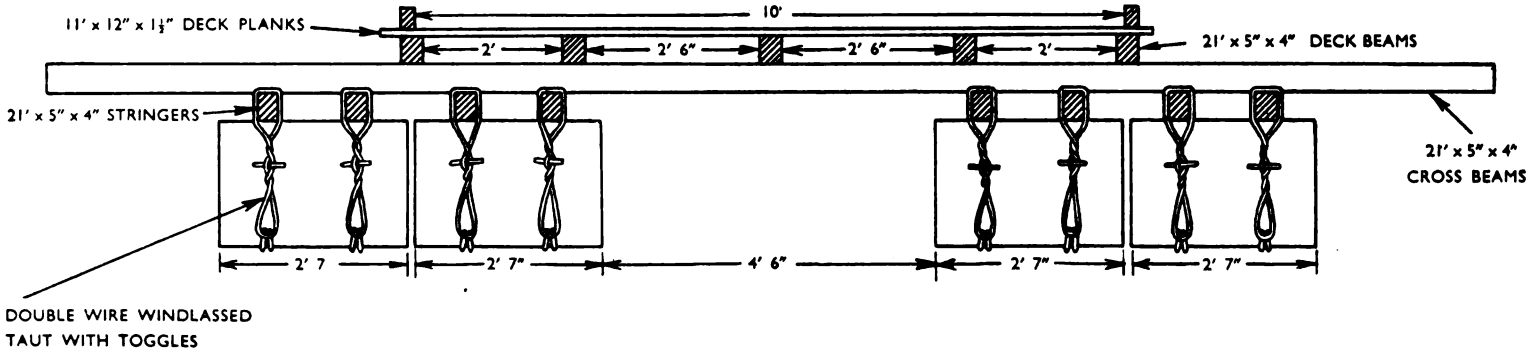
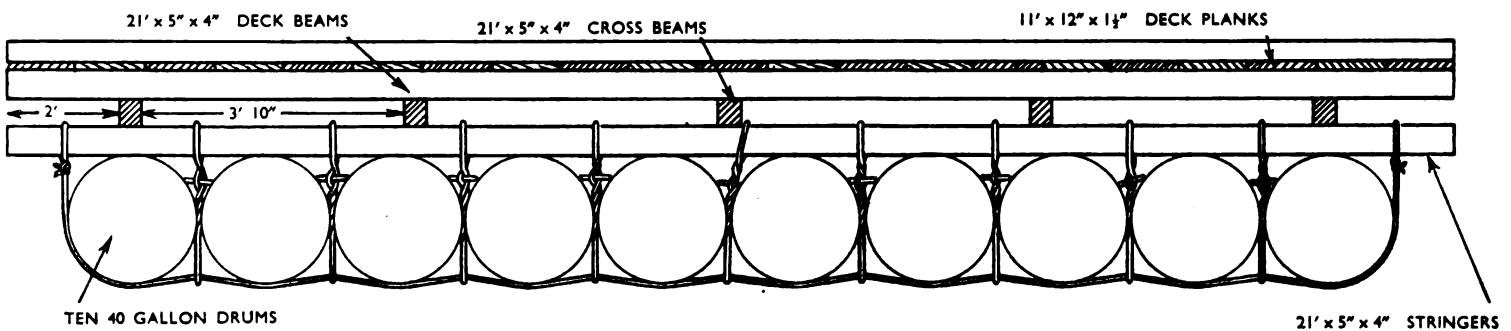


SECTIONAL VIEW



SIDE VIEW

Fig. 72. A timber and drum raft

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weight. The pull required to haul a sleigh up a slope is found by the formula

$$P = W \times S + \frac{W}{20},$$

where P is the pull, W is the weight, and S is the gradient.

Example :

To move a 10-ton sleigh up a slope of 1 in 5 :

$$P = 10 \times \frac{1}{5} + \frac{10}{20} = 2{\cdot}5 \text{ tons.}$$

If a roller is cut to slew the sleigh the pull is doubled, and if all the rollers are cut the pull is trebled.

RAFTS

If the loads to be disembarked are either too heavy or too bulky for transport by the ship's boats some form of raft must be improvised, unless the load can be floated ashore. Some forms of raft are described below, but in constructing a raft for a particular purpose much depends on the materials available and the ingenuity of the seaman on the spot.

Buoyancy

The safe buoyancy of a spar can be found by the formula $B = \frac{9}{10}(VM - VN)$, where B is the buoyancy in pounds, V is the volume of the spar in cubic feet, M is the weight in pounds of a cubic foot of water (*i.e.*, 62½ lb. for fresh water and 64 lb. for sea water), and N is the weight in pounds of a cubic foot of the wood from which the spar is made (see the table on page 234 for weights of various types of wood).

The safe buoyancy of a drum can be found by the formula $B = 9C$, where B is the buoyancy in pounds, and C is the capacity of the drum in gallons. If the capacity of the drum is not known its safe buoyancy can be found by the formula $B = 4{\cdot}5\ C^2L - W$, where B is the buoyancy in pounds, C and L are respectively the circumference and length of the drum in feet, and W is the weight of the drum in pounds.

Types of Rafts

An ordinary raft consists of two baulks of timber forming the side stringers, with scantlings lashed or bolted across them to form the beams, and planks nailed on top of the scantlings to form the deck. The length of the stringers should be twice the width of the deck. Additional buoyancy can be obtained by lashing drums or barrels under the beams and between the stringers.

When loading a raft with men or stores it is best to begin amidships on each side and work forward and aft simultaneously along the sides towards the ends ; then load the remaining deck space working from amidships towards each end. The raft will thus be loaded symmetrically, and any tendency to tilt will be minimised.

When disembarking men or stores from a raft on to a bank in deep water, one or more gang-planks should be placed with their feet resting along the centre-line of the raft, so as to avoid unsymmetrical off-loading and the possibility of the raft listing or capsizing.

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If drums or barrels are used to provide extra buoyancy they should be lashed with their bungs uppermost and accessible from the deck of the raft. Then if they leak they can be pumped out with a portable bilge-pump and hose.

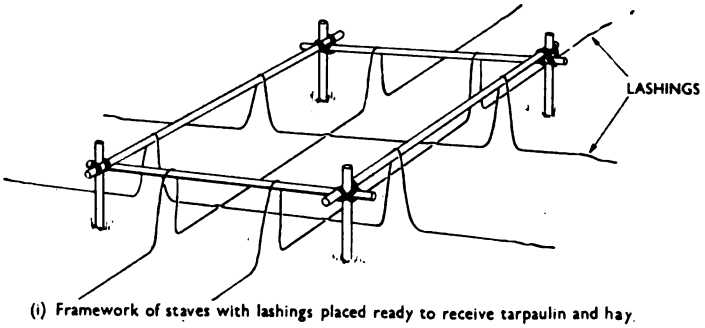
Timber and Drum Raft

A raft capable of carrying a loaded 30-cwt. lorry (total weight 4½ tons) is illustrated in Fig. 72. It is constructed of eighteen 21-ft. scantlings of 5 in. × 4 in. timber, twenty-one planks each 11 ft. × 12 in. × 1½ in. and forty 40-gallon drums of the type used for road-mending.

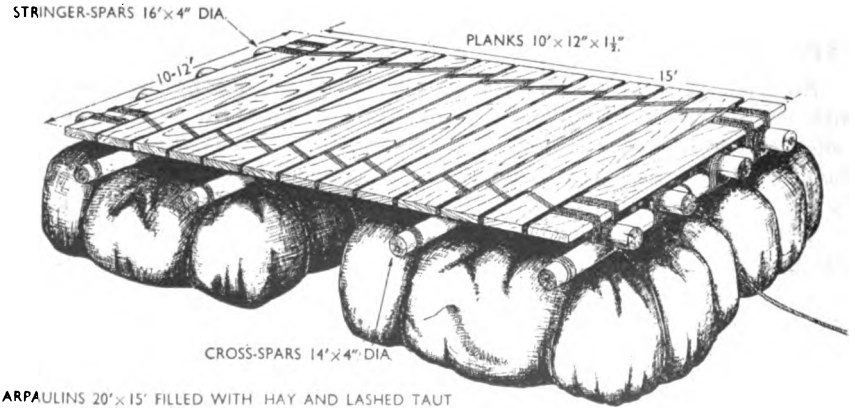
The eight stringers are laid 1 ft. apart in two sets of four with a distance between the sets of 5 ft. The drums are lashed in pairs below each set of stringers, the lashings being tautened by toggles, as shown in the illustration. The five cross-beams are lashed or bolted across the tops of the stringers 3 ft. 10 in. apart. The five deck-beams are lashed or bolted across the tops of the cross-beams, the inner ones being 2 ft. 6 in. apart and the outer ones 2 ft. from the inner ones. The twenty-one planks are nailed across the deck-beams to form a deck 21 ft. long and 10 ft. wide, and 2-in × 3-in. scantling is nailed on the top of the ends of the planks to form a foot-rail on each side of the deck.

Tarpaulin and Hay Raft

Where the necessary timber and drums are not available a raft can be made



(i) Framework of staves with lashings placed ready to receive tarpaulin and hay.



(ii)

Fig. 73. A tarpaulin and hay raft

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by stuffing tarpaulins with straw, ferns, heather or other similar material and lashing them below spars as shown in Fig. 73.

The materials required to make a raft capable of carrying a 24 cwt. load are :—

4 tarpaulins, each 20 ft. × 15 ft. ;
1½ tons of straw ;
15 planks, each 10 ft. × 12 in. × 1½ in. ;
8 spars of 4 in. mean diameter, four of 16 ft. and four of 14 ft. ;
4 staves, each 7 ft. long ;
70 fathoms of 1½-in. cordage for lashing the tarpaulins ;
80 fathoms of 1-in. cordage for spar lashings.

The staves are lashed together to form a framework 6 ft. square supported 2½ ft. above the ground, and four lashings, each about three fathoms long, are laid across the framework, two each way. A tarpaulin is then placed in the framework and filled to the top of the framework with straw, well trampled down. The sides of the tarpaulin are then folded across the top of the straw and the whole is lashed into a compact bundle.

Two of these floats are then lashed to two 14-ft. spars to form one half of the raft, the other half being made in the same way. The two halves are then placed three feet apart and lashed to the four 16-ft. spars, across the tops of which are lashed the 15 planks to form a deck 15 ft. long and 10 ft. wide.

The actual buoyancy of the raft is considerably more than 24 cwt. but a reserve of buoyancy is necessary because of the short length of the raft in relation to its width and because of the materials used in its construction.

If the tarpaulins are in good condition the raft should retain its buoyancy in water for at least eight hours.

Floating a Vehicle in a Tarpaulin

A light saloon car or similar vehicle can be floated ashore by wrapping it in a tarpaulin.

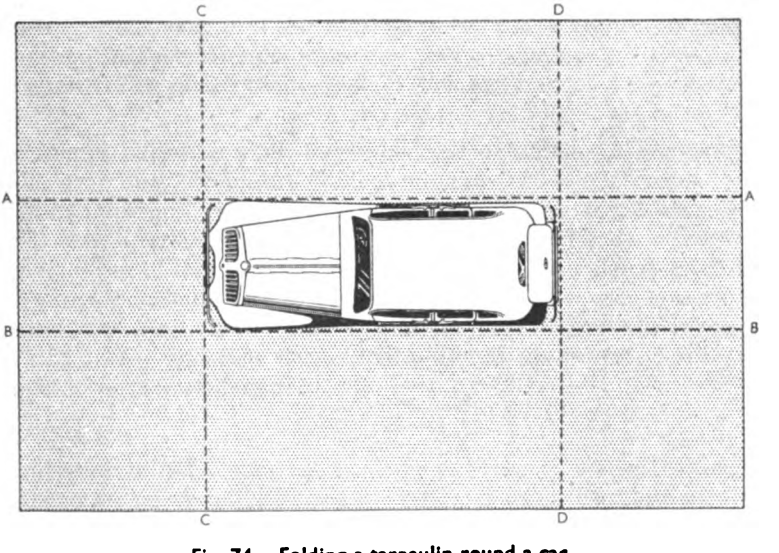

Fig. 74. Folding a tarpaulin round a car

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The tarpaulin is laid flat on the deck and the car is run on to it. The tarpaulin is then folded over the car in the following manner (see Fig. 74) :—

first fold the sides along the lines AA and BB, and secure by lashings passed across and over the car ;

next fold the ends along the lines CC and DD, and secure by lashings passed from front to rear and over the car ;

now fold and lash the corners into dog's-ears, and secure them by a lashing passed round the sides and ends of the car, and finally lash each corner to the corresponding corner on the other side.

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CHAPTER XII

Fire-fighting

THE CHAPTER on fire-fighting in Volume II of this manual gives a general description of the causes of fire, the principles and methods of extinguishing fires, and the fire-fighting equipment available in H.M. ships. This chapter deals with the organisation of precautionary and preventive measures against fire, the direction of fire-fighting, additional hazards from fires, details of fire-fighting equipment and installations, and the fire-fighting arrangements in merchant ships.

Organisation

Fire Parties

A duty fire party must always be detailed and be ready to answer a call immediately by night or day, and an officer must be detailed to take charge of operations. The party should, if possible, consist of the following :—

a chief or petty officer ;
from four to six seamen or stokers ;
one or two electrical ratings, for rigging temporary leads, etc. ;
an engine-room artificer or stoker petty officer for magazine flooding or spraying ; and
a shipwright.

This party is considered large enough to deal with any medium-sized outbreak of fire, but it may have to be augmented considerably if large-scale operations become necessary. Consideration must therefore be given to the provision of a reserve of men to back up the fire party, but it should be borne in mind that too many men in the fire area may well result in overcrowding and chaos. Strict control of the men in the fire area is vital, because there is a tendency in such circumstances for men to display misplaced gallantry or take undue risks, which often result in casualties and a complication of the issue.

Care should be taken when mustering and detailing the fire party before they take over duty, to ensure that every man knows his duties. In most ships fire equipment is stowed in two or more readily accessible positions, a complete outfit of essential gear being kept available at each. The fire party is mustered at one of these when the alarm is given ; each man is specifically detailed to provide certain items of equipment, and he then goes to the fire. This arrangement ensures that the fire party arrives at the fire with adequate gear to start operations, and that the normal outfit of equipment is not disturbed unless operations are prolonged.

Fire Patrols

Organisation of patrols for the regular inspection of all parts of the ship is most important, particularly at sea in war, and when the ship is in dock or refitting. Men detailed as patrols should be highly trained in fire-fighting so that they deal correctly in its early stages with any fire they discover.

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Training

Exercises in as realistic a form as possible should be carried out frequently on board ships, and where practicable every man in the ship's company should be given a course once a year at one of the fire-fighting schools established at each of the main ports at home and abroad.

Maintenance and Stowage of Equipment

The equipment must be constantly maintained in a state of instant readiness, otherwise valuable time may be lost when fire occurs. After use, whether for exercise or at a fire, the equipment must be serviced, recharged, and replaced ready for use.

Dispersal of equipment is necessary to ensure that the whole equipment is not destroyed or rendered inaccessible in the event of damage and/or fire in one part of the ship. The general policy is to stow the gear at "fire posts," two of which are established in each damage control section of the ship, and at which are placed fire-lockers to accommodate loose gear. In the vicinity of each fire-locker is assembled a variety of hand fire-extinguishers and other equipment. Hand fire-extinguishers are also usually stowed inside, and near the main access to, any compartment in which there is any particular risk of fire. Consideration should be given to placing equipment in positions which are readily memorised, so that they may be more readily found in darkness or dense smoke.

Stowage and Treatment of Inflammable Materials

The use of inflammable materials in the structure and fittings of ships has been reduced to the minimum consistent with a reasonable standard of habitability, and special arrangements have been made for the stowage of highly inflammable liquids and materials. Much that is essential for personal use or comfort, however, such as clothing, bedding, curtains, oilskins and towels, still constitutes a grave fire and smoke risk. The ship's organisation must therefore allow for such articles to be stowed away, or rolled up in bundles, and damped down when action is imminent.

Rendering materials fire-resistant.—There is no known permanent method by which a material can be rendered fire-resistant without adversely affecting its texture. Textiles, however, can be made reasonably fire-resistant by treating them with a solution of ten ounces of borax, eight ounces of boric acid and one gallon of water.

Articles should be immersed in the solution for about one hour, then be very lightly wrung out and laid flat to dry.

Re-treatment is necessary every six months, and on every occasion after wetting.

Handling and stowage of explosives.—The precautions concerning the handling and stowage of explosives are clearly laid down in the *Naval Magazine and Explosive Regulations*. It is essential that these regulations be brought to the notice of all on board, and that they are fully understood and rigidly enforced.

Reduction of paint.—The thickness of paint on bulkheads must be kept to a minimum, and should not normally exceed two coats, or at the most three, otherwise the spread of fire from one compartment to another is likely to be facilitated.

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Direction of Operations

The first measures for dealing with a fire are taken by the man who discovers it, and usually, if attacked quickly and correctly, major measures will not be necessary. If, however, the fire is large, or develops quickly, it is essential for operations to be directed by a responsible officer or senior rating, who must assess the situation thoroughly, control all fire-fighters and order the methods to be employed.

The duties of the officer-in-charge are to move around the fire area and keep himself informed of the situation as a whole ; to make sure that the fire is not spreading ; to look for and take precautions against possible complications ; and to instigate every action possible to ensure the safety of the fire-fighters. He should not, however, take any active part in the fire-fighting himself.

A control point should be established as soon as possible, and for this purpose it is recommended that the nearest Damage Control base should be used, because it has ample telephonic communication, is supplied with plans of the ship and is in direct communication with A.B.C.D. Headquarters, which should be kept informed of all developments and progress.

Although speed is essential in the first attack on a fire, if the first simple measures fail a careful summing up of the situation is at least as important. The officer-in-charge, having thoroughly assessed the situation, will then be in a position to choose the most suitable technique and call for the necessary appliances.

Important Questions at a Major Fire

The questions below give an indication of the matters which must be considered at a major fire, and when an officer or key rating takes charge he must immediately deal with them.

(i) What is burning ?
(ii) Where is the seat of the fire ?
(iii) How can access be obtained ?
(iv) What appliances are needed ?
(v) Is sufficient water available from the firemain ?
(vi) What is threatened ?
(vii) What precautions must be taken to prevent the fire spreading ?
(viii) How can the construction of the ship be used to aid the extinction, or prevent the spread, of the fire ?
(ix) Where should the fire boundaries be established ?

From these broad considerations, the following, more detailed, questions arise :—

(i) Has A.B.C.D. Headquarters been informed ?
(ii) What dangerous gases or vapours, if any, are likely to be present ? Is breathing apparatus necessary ?
(iii) Is it necessary to spray adjacent bulkheads ?
(iv) Is it necessary to remove inflammable materials from contact with bulkheads or decks ?
(v) Is it likely that spraying or flooding of a magazine or other dangerous compartment will be necessary ? Are the flooding keys at hand ? Is there a responsible rating present to carry out the spraying or flooding if necessary ?

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(vi) Is smoke travelling in such a way as to give a false impression of the position of the seat of the fire ?
(vii) Is it advisable to close down the compartment and keep it closed down ? Have ventilating fans been stopped ? . Is it necessary to close the ventilating trunks ?
(viii) Are additional appliances required from other parts of the ship ?
(ix) Are additional pumps required on the firemain ?
(x) Are additional hands required ? Can they be mustered quickly and easily ?
(xi) Is the stability of the ship threatened ? Has provision been made for pumping out excess water ?
(xii) Should any electrical circuits be broken ?
(xiii) Are there any high-voltage electrical circuits in the fire area ? Is there W/T, radar, or asdic apparatus in the vicinity ?
(xiv) Would a change in the ship's course assist the fire-fighting operations ? Does the fire situation warrant such a request ?

When the fire is under control it should be considered whether :—
(i) It is expedient to open up compartments for inspection.
(ii) It is safe to ventilate the compartment with the object of clearing the smoke.

When the fire appears to be out, the following questions arise :—
(i) Is the fire really out ? Are any materials still smouldering ?
(ii) What steps should be taken to prevent re-ignition ?
(iii) What damage has been done to electrical apparatus ? What precautions are advisable in this respect ?

Access to the Fire

In a ship, approach to a fire from the most favourable angle is seldom possible. Most compartments below the waterline can only be entered from above, and this access will probably be the only outlet for the smoke and fumes. Fighting fires caused by enemy action may be complicated by jammed doors and hatches and twisted structure, and it is imperative that great care should be exercised in approaching a fire in these circumstances. Damaged bulkheads and decks, however, often allow access to a fire from a more favourable angle than would otherwise be possible.

Broadly speaking, a fire may be assumed to be accessible if branch pipes can be directed to its seat through hatchways, doors, or other openings.

Improvisation

No two fires are identical and therefore no rules of procedure can be laid down. Improvised methods of reaching the seat of the fire are often necessary, and their nature will depend upon the prevailing conditions. The following are some examples of improvisation.

(i) Fig. 75 (i) and (ii) shows two examples of methods used to direct water on to the seat of a fire which is otherwise inaccessible.
(ii) Cutting a hole in a bulkhead or deck through which to insert a branchpipe may be justified, but the advantages to be gained must be weighed against the adverse effect on watertight integrity, and this expedient should be avoided and the main bulkheads and decks kept intact if possible.

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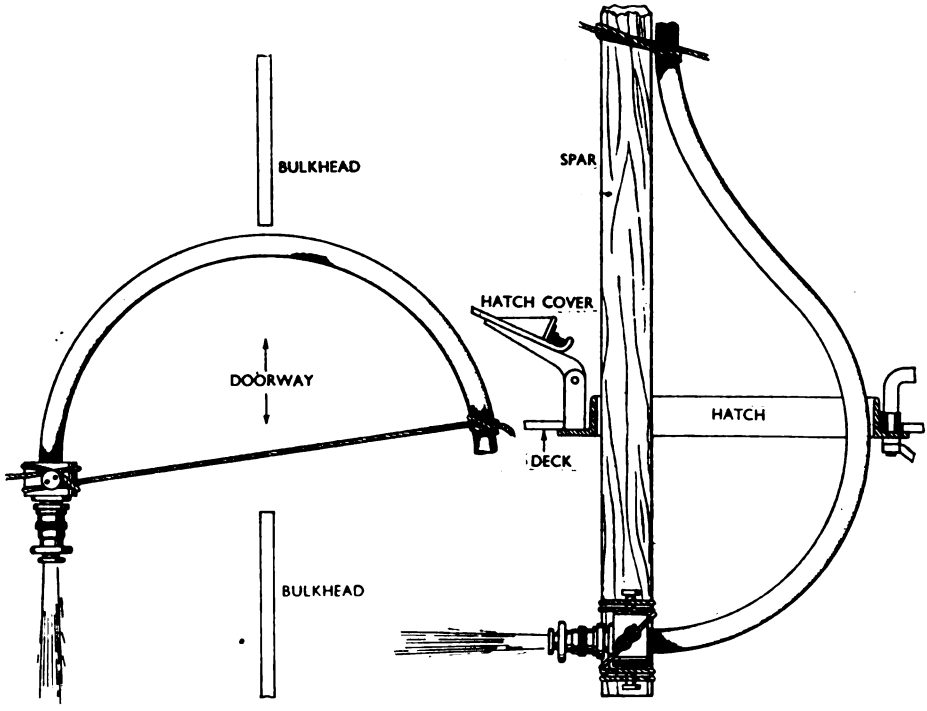
(iii) Lowering a man over the side to direct a branchpipe through an open scuttle, or a hole made by a shell or splinters, has proved effective.

(iv) Portable pumps may be used to boost the firemain pressure high up in the ship if damage has reduced it.

(v) The bulkhead emergency connections should be used to run lengths of fire-hose through the ship, thus enabling watertight doors to be kept closed.



(i) Method of rigging a hose through a doorway to direct the water-jet to the side of an adjacent compartment

(ii) Method of rigging a hose through a hatch to direct the water-jet to the side of the compartment below

Fig. 75. Methods of rigging hoses

Stability and Fire-fighting

The effect of the extensive use of water in fire-fighting on the stability of the ship is not generally realised, and is likely to be overlooked at the scene of a fire. As further damage in other parts of the ship may render the stability situation critical if more water is added during fire-fighting, it is essential to maintain a close liaison with A.B.C.D. Headquarters and to consult them before any major flooding is undertaken. A.B.C.D. Headquarters must remain the overriding authority on all damage counter-measures and it may be in a position to dictate the fire-fighting technique to be adopted.

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When fire-fighting the following points must be borne in mind in relation to stability :—

(i) Water in an outer compartment of the ship will result in unsymmetrical loading and cause a list.

(ii) Water in a compartment high up in the ship will add topweight and reduce stability.

(iii) Partially flooding a compartment will create a free-surface effect. Whether situated centrally or to one side, there will be a virtual reduction in metacentric height, roughly proportional to the length multiplied by the *cube* of the breadth of the compartment.

(iv) Flooding a compartment low in the ship, while possibly increasing the righting forces, will reduce freeboard and reserve of buoyancy.

(v) Loose water in a compartment must be removed as soon as possible.

(vi) When water from a flooded compartment is used for fire-fighting the mean draught of the ship will not be affected, but a change in the loading of the ship will result. A free-surface effect will also be created, both in the compartment from which water is being drawn and in that to which it is being pumped. There is also a grave risk that such water may be contaminated with oil-fuel. The operation must therefore not be undertaken without due consideration of these factors.

Estimation of the Quantity of Water being used.—It is essential that a close check of the quantity of water being used should be kept, for the following reasons :—

(i) to enable A.B.C.D. Headquarters to assess its effect on the stability of the ship ;

(ii) to equate it to the output of the pumps connected to the firemain, and to ensure that the firemain pressure available is adequate to operate the appliances efficiently.

Ships' pumps in destroyers and larger ships usually have an output at full speed of 50 or 75 tons per hour. These pumps can therefore supply water for three or five jet/spray nozzles working as jets at a pressure of 50 lb. per sq. in.

The following table gives the quantity of water discharged by the various branchpipes at various pressures in tons per hour.

WORKING PRESSURE LB./SQ. IN.	WATER		OILFIRE NOZZLE	FOAM		
	JET/SPRAY NOZZLE					
	90° SPRAY	JET		F.B.2 (P)	F.B.2 (S)	F.B.10 (P)
35	23	13	13·5	10	15·3	22
40	24·75	13·5	14	11	16	23·5
50	28	15	15	12	17·75	26·5
60	31·5	15·5	16·5	13	19·75	29
75	34·5	16	19	15	22	32·5

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If, for example, four jet/spray nozzles are in use, two as jets and two as sprays, and the pressure at the nozzle is 35 lb. per sq. in., the total output will be 72 tons of water per hour. If one 75-tons-per-hour pump is supplying that section of the firemain and it becomes necessary to bring more appliances into use, an extra pump will have to be started, otherwise the nozzle pressure will fall below 35 lb. per sq. in. which is the minimum pressure at which the appliances are designed to work effectively.

Re-ignition

The dangers of using more water than is absolutely necessary have been stressed, but there is also the danger that unless the fire is completely extinguished and the vicinity cooled it may light up again. It is therefore essential that when the fire appears to be out a thorough inspection be made to ensure that no smouldering materials remain. Similarly, when an oil fire has been extinguished by using foam, the foam blanket must remain intact until the oil has cooled down, and particular care must be exercised when the ship is rolling that the foam blanket does not break at the edges or around bilge obstructions, as this might allow the fire to re-ignite.

Additional Fire-fighting Hazards in Ships

Dealing with a fire involving any one material in a single space is straightforward, but owing to the complex nature of a ship's equipment there will always be additional hazards to complicate fire-fighting operations. Some of these hazards are described in the following paragraphs.

Changes in Electrical Loading

The insulating material of electrical systems in the fire area may be charred through, causing shorting and hence changes in the loading of certain circuits. Patrols must therefore be organised to inspect spaces remote from the fire area, and to watch for any subsidiary fires in electrical systems, for some time after a fire has been extinguished. For the same reason the electrical loading of circuits must be carefully checked at the main switchboard.

Liquid Fuels

Liquid fuels in the vicinity of a fire constitute a serious complication, and for the correct assessment of the risk involved a knowledge of how liquid fuels can be ignited is essential. The principles described below apply to all inflammable liquids.

Before a liquid fuel can become ignited the temperature of the fuel, or of some part of it, must be such that sufficient vapour is produced to form an inflammable mixture with air. With the heavier fuels, such as oil fuel for boilers, the liquid must be heated before it can be ignited ; with petrol, however, and certain other highly inflammable liquids, sufficient vapour is produced at normal atmospheric temperatures, or even at temperatures below the freezing point of water, to allow ignition to take place when a spark or flame is applied.

A mixture of fuel vapour and air is inflammable only within certain proportions, which are known as the " limits of inflammability." For petrol, these limits, expressed in a percentage by volume of vapours to air, are from

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1·4 to 7·5 per cent. Petrol vapour is heavier than air and at the surface of the liquid the mixture may be too rich to burn, but there is bound to be a portion of the mixture in the vicinity which is in the correct proportion for ignition to take place; this is illustrated in Fig. 76. Once ignited, turbulent conditions are set up, more vapour and air mix, and combustion will continue until the fuel is consumed. When a partially filled oil fuel tank is in the fire area the possibility of there being an explosive mixture in the tank is remote. There is, however, a danger of ignition should the bulkhead become red hot near the surface of the oil. Such a fire would be of short duration in a closed tank, owing to the limited amount of oxygen available.

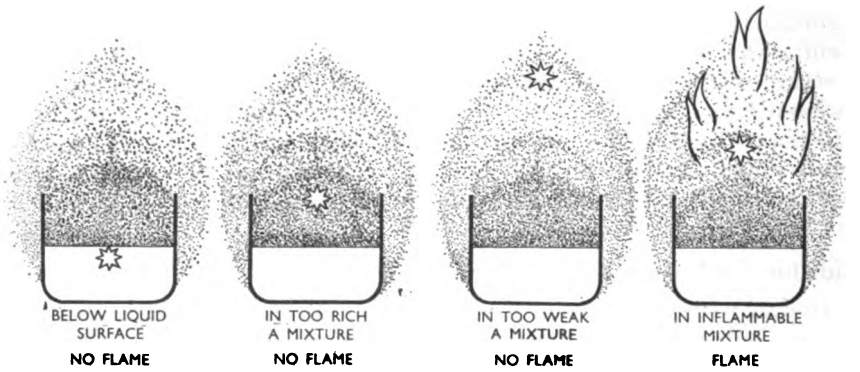

Fig. 76. Petrol vapour—how it ignites

A further possibility is that the seams of the tank may open up and so allow oil to leak into the fire area; should this occur the tank must be emptied. Provided, however, that leakage has not occurred, it is preferable to fill the tank to 95 per cent. of its capacity and then top it up with water if necessary, thus avoiding structural damage due to heat. Regard must, of course, be paid to the effect of such action on the heel and trim of the ship.

Explosives and Fireworks

Explosives and fireworks of all kinds present a serious complication when fire occurs in a ship. Fixed installations are provided for protecting magazines and certain other spaces where explosives or highly inflammable stores are stowed. In addition, there are water drenching systems to protect cordite charges at positions associated with magazines and gun mountings.

Ready-use ammunition lockers containing cased ammunition, which are not fitted with flooding and spraying arrangements, should be cooled with branchpipes if there is any danger of them becoming heated from an adjacent fire.

Gas Cylinders

All cylinders containing compressed gases must be considered as being highly dangerous if near a fire. They should be removed from the fire zone, or, if this is impossible, they should be kept cool by water-spray to prevent

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them from bursting through the expansion of their contents by the heat from the fire.

Cinema Film

The basis of 35 mm. film is nitro-cellulose, which is highly inflammable and gives off combustible poisonous fumes when heated. As the film contains its own oxygen, decomposition may continue even when the film is completely immersed in water.

In a confined space the fumes given off are highly explosive, and it is therefore essential to prevent them from accumulating by thoroughly ventilating the space concerned.

Should a film take fire it should be left to burn itself out (which it will do very quickly), but steps must be taken to control the fire and prevent it from spreading by removing other combustibles and by cooling the surroundings with water-spray.

Dangerous Gases

When fuel containing carbon is burning in a plentiful supply of air carbon-dioxide will be formed, and although this gas is not strictly toxic it will not maintain life. If, however, the supply of air is limited, as it will be if in an enclosed space, combustion will not be complete and so carbon monoxide, an odourless and highly toxic gas, will be produced ; this gas is also present in the exhaust from internal combustion engines.

A further danger to life in the vicinity of a fire is lack of oxygen for satisfactory breathing, because the fire may consume nearly all the oxygen in the surrounding air. A useful guide to the condition of the surrounding air may be obtained by observing the state of the fire. If it is burning freely and little smoke is being given off combustion will be complete and there should be ample oxygen in the vicinity. On the other hand, if the fire is burning fitfully and emitting heavy smoke, the supply of oxygen is inadequate and there is danger of the presence of high concentrations of carbon dioxide and probably of carbon monoxide.

Some of the media used for fire-fighting purposes add to the toxicity dangers. Carbon dioxide is sometimes used and it is dangerous to breathe. Methyl bromide, used in the fixed installations of petrol-engined craft, is highly toxic. Carbon tetrachloride vapour is also toxic. The products of decomposition of both methyl bromide and carbon tetrachloride are equally dangerous when these liquids are used on a fire, the latter giving off phosgene gas which quickly irritates the nose and throat.

A further danger arises when entering compartments adjacent to a fire which have been closed for a considerable time. Paint absorbs oxygen while drying, and if the compartment remains closed for some time after painting the atmosphere will lack oxygen.

Lack of oxygen may also arise from an explosion, a large proportion of the oxygen in a compartment being then consumed. It is therefore dangerous to enter an area in which an explosion has occurred unless breathing-apparatus is worn.

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The following table gives comparative details for the toxicity of various gases and vapours :—

GAS OR VAPOUR	PHYSIOLOGICAL REACTION	APPROX. CONCENTRATION % IN AIR		
		RAPIDLY FATAL	DANGEROUS FOR ½-HOUR EXPOSURE	MAXIMUM CONCENTRATION FOR PROLONGED EXPOSURE
Carbon dioxide	respiratory stimulant	5—10%	3—4%	0·5%
Carbon monoxide	asphyxiant	0·4%	0·2%	0·01%
Carbon tetrachloride	anæsthetic	1—4%	0·2%	0·15%
Phosgene ...	irritant	0·09%	traces	traces
Methyl bromide	anæsthetic	0·2—0·5%	traces	traces
Petrol ...	anæsthetic	6—8%	0·6%	0·2%
Chloroform ...	anæsthetic	2·5%	1·4%	traces

The dangers from toxic gases and vapours have been stressed at considerable length because of the necessity for avoiding risks. A casualty in the fire area is an unnecessary complication, and it requires the attention of several men for rescue work when their services can least be spared from fire-fighting.

The breathing-apparatuses supplied, namely the " Salvus," the compressed air, and the Pattern 230 breathing-apparatuses, give complete protection against dangerous gases and vapours, and they should be worn if there is the slightest doubt as to the purity of the atmosphere for breathing.

It is once more emphasised that the Service anti-gas respirator should not be used in the fire area or in a compartment where the air may be foul, because it merely filters the existing air and cannot make up for lack of oxygen. It does, however, afford limited protection in smoke and may be used in emergency for escape purposes only.

Potential Causes or Sources of Fire

Seepage of Inflammable Liquids and Vapours

Highly inflammable liquids and their vapours are extremely liable to seepage, and bulkheads and pipejoints which are normally watertight may allow such liquids or vapours to seep past or through them. Care must therefore be taken to ensure that no dangerous vapours are present in spaces near petrol systems before any work involving sparks or heat is undertaken.

Static Electricity

Many fires have been started by a spark caused by the discharge of high-potential electricity generated by friction in the filling-hose during the delivery of petrol ; others have been caused by the different electrical potentials of the vessels or craft concerned. To avoid this danger arising when petrol is being

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transferred by hose, the hose-end and the tank which is being filled must be bonded or earthed, so that any charge generated will be dissipated harmlessly.

W/T, Radar and Lightning

Transmission on ship's W/T and radar sets is liable to induce electric currents at voltages which may be a source of danger during the embarkation and handling of inflammable stores and liquids, *e.g.*, when aircraft are being fuelled. When such work is being carried out, no transmission is therefore to be allowed on radar sets, and transmission is only to be permitted on W/T transmitters which have a rated output of 50 watts or less. For the same reason such work must be suspended during a thunderstorm.

Spontaneous Combustion

Under certain conditions spontaneous combustion can occur in fibrous materials when impregnated with oil, through the chemical action of the oil on the material generating heat which, if unable to dissipate, will eventually cause the material to burst into flame. This chemical action and generation of heat will obviously be accelerated if the material is stowed near a steam pipe or other source of heat.

Rags and waste used for mopping up oil are the most common sources of this fire hazard, and care must be taken that such materials are disposed of safely and quickly. Bagged foodstuffs, painted canvas and charred wood are other examples of materials liable to spontaneous combustion.

Welding and Burning

Welding and burning are used extensively in the building and repair of ships, and the sparks given off when this work is in progress, also the heating of the plates involved, constitute a serious fire risk. Great care must be taken that fire-extinguishers are at hand while such work is in progress, and also that watch is kept on the other side of the deck or bulkhead being welded or burnt to ensure that a fire does not start there.

Any space in which welding or burning has been carried out, and all spaces adjacent to it, should be carefully patrolled after work has ceased to ensure that no smouldering materials remain.

Harbour Risks

Extra vigilance in fire precautions is necessary when a ship is in a dockyard or a port because refitting work is then frequently in progress, and a proportion of the ship's pumps may then be under repair. Fire in a ship in harbour may endanger other ships or nearby shore installations. Shore fire services, however, are readily available, and whether assistance is required or not the dockyard authorities must be informed immediately a fire is discovered.

Floating Oil or Petrol.—An additional fire risk, sometimes present in harbours or basins, is oil or petrol floating on the water, which if ignited will endanger all ships in the vicinity. A layer of burning liquid can be driven with water jets to some position where it will do no harm, and there be extinguished with spray or foam. Another useful method of driving burning liquid in the required direction is to use the wash of a ship's power boat, preferably a diesel-driven one.

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Ships in Dry-dock.—The danger of fire spreading in a ship in dry-dock is increased because the cooling effect of the water on the hull of a ship when floating is absent.

In accordance with the *Naval Magazine and Explosive Regulations*, hoses must be rigged from all available dockyard hydrants, and be connected to the ship's firemain and to the flooding bonnets fitted over the sea inlets to the magazine flooding systems.

In the event of a fire the demand for water may exceed the capacity of the water-mains feeding the ship's hydrants, and the ship's portable emergency pumps should be kept ready for providing the additional water required from any nearby water supply.

Emergency Pumping

The chief use of the portable emergency pumps carried in ships is to provide water under pressure should the firemain be damaged.

The standard emergency pumps are diesel-driven, and are therefore entirely independent of any other source of power. They are supplied to some destroyers and to all larger ships, smaller ships being provided with a two-man manual pump.

The electrically driven portable salvage pump may also be used in certain circumstances to provide water for fire-fighting.

Diesel-driven Emergency Pumps.

These pumps have a suction-lift of up to 25 feet above the surface of the water supply. Their output is 27 tons per hour at a discharge pressure of 50 lb. per sq. in., but it must be borne in mind that the discharge head will reduce

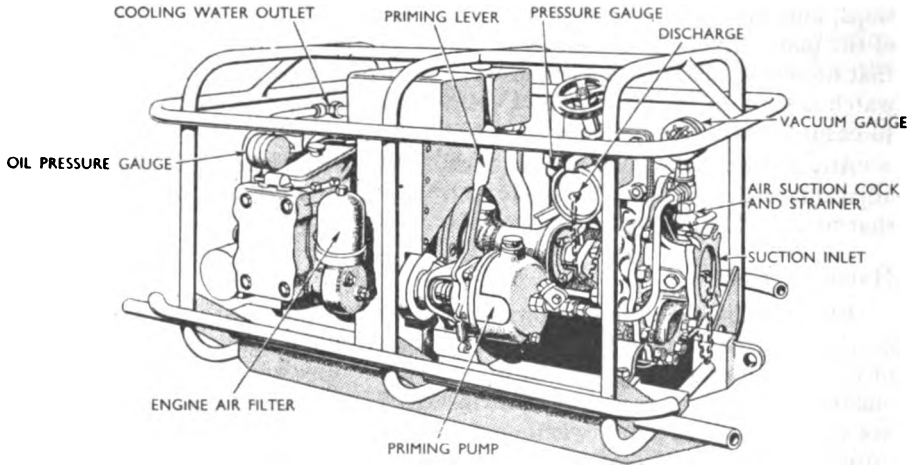

Fig. 77. A diesel-driven portable pump

the effective discharge pressure and the output. In this connection it is useful to remember that a pressure of one lb. per sq. in. will raise water in a hose to a height of approximately two feet. Thus, if a pressure of 50 lbs. per. sq. in. is showing on the pump-discharge pressure-gauge, and a branchpipe is being operated at a position 40 feet above the pump, a pressure of only 30 lb. per sq. in. would be available to overcome friction losses within the hose and for

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conversion to velocity at the branchpipe, with the result that the discharge would be poor.

The main pump of this unit is of the centrifugal type and is not self-priming ; that is, it will only deal with water, and not air or even air and water. A small priming-pump is therefore built into the unit for exhausting the air from the suction-line, and thus priming the main pump, when the pump is operated above the level of the water supply. This priming-pump is engaged by hand at the start of pumping operations, and is held in place until the main pump is sucking water ; the priming-pump is then released, and it is thrown out of engagement by a spring. The priming-pump must itself be primed before use by removing the plug at the top of its casing and filling the pump-chamber with clean water.

When these diesel-driven pumps are used between decks, flexible extension-pipes must be fitted to the engine exhaust-pipes to carry away the exhaust fumes to the open air, and these extension-pipes are provided as part of the pump outfit.

70-ton Electrically driven Salvage Pumps.

These pumps are primarily for salvage work, but can be adapted easily for fire-fighting and will supply one or two jet/spray nozzles with water at a reasonable pressure. They are self-priming, a priming-pump for clearing the suction-line of air being incorporated in the unit, but the priming-pump itself must be primed by filling its casing with clean water before use. The electric salvage pump is capable of taking a suction-lift of up to 25 feet above the level of the water supply, but it is not designed to give such a high pressure as the diesel-driven pump, and therefore cannot be expected to supply water at pressure to such heights as the latter.

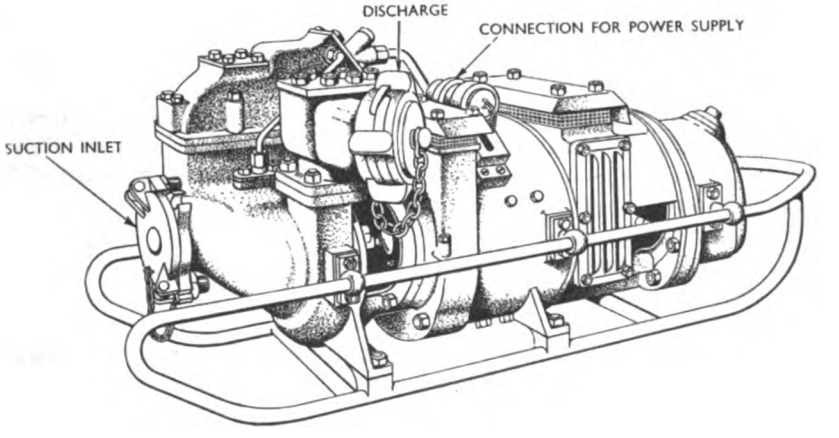

Fig. 78. 70-ton electrically-driven portable pump

Internal Stand-pipes for Portable Pump Suction

To enable suction to be obtained from the sea when the ship is under way at speed, internal stand-pipes are provided before and abaft the main machinery spaces, and fitted with swing-bolt suction-hose connections to which the suction-hose of a portable pump can be connected. Destroyers are fitted with two stand-pipes, and larger ships with four.

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Two-man Manual Pumps

As the name implies, this pump is manually operated, and it is therefore independent of any other source of power. The pump is self-priming, and when operated at 60 double-strokes a minute it will take a suction-lift of up to 15 feet. At this speed, and with a suction-lift of 10 feet, it will produce a good jet at 30 lb. per sq. in. with the special $\frac{5}{16}$-in. nozzle supplied. The F.B.O. foam branchpipe is supplied for foam making in conjunction with the two-man manual pump and the knapsack foam-compound unit.

The suction-hose of the manual pump has screwed couplings, and suction is obtained by lowering the hose over the ship's side. It cannot be connected to the internal stand-pipes.

First-aid for Burns

First-aid for a burn should be carried out at once, either by the victim himself or by the nearest available person, the object being to relieve pain and prevent further injury. This is most easily and quickly done by protecting the burned surface from the air, and it should therefore be covered, in the same way as a wound, with a clean, dry dressing, which should be widely and firmly secured. One or more first-aid field dressings, or any improvised pads of clean material folded to appropriate sizes, are suitable.

Never attempt to pull off anything adhering to burns on the body, and never touch the surface of a burn or attempt to clean it.

A victim who is burned will suffer from shock. First-aid for shock must therefore be administered as follows :—

(i) lay the victim flat in a safe place ;
(ii) get him warm ;
(iii) give him a hot sweet drink ;
(iv) if he is in pain give him morphia.

Fire-fighting Arrangements in Merchant Ships

The minimum standard of fire-fighting equipment to be carried in merchant ships is laid down in the statutory rules and orders provided under the *Merchant Shipping Act*, and the number and types of appliances to be carried vary accordingly to :—

(i) the size of the ship ;
(ii) whether she carries passengers or cargo, or both ;
(iii) the type of cargo carried ; and
(iv) whether she is steam- or motor-driven.

A general description of the fire-fighting equipment in a large, ocean-going merchant ship is given in the following paragraphs.

Fixed Systems

Firemain.—This system, known in the Merchant Navy as the " wash-deck service," supplies hydrants suitably disposed about the ship. Water is delivered to the system by pumps, which in the older ships are all in the engine-room, but in modern ships they must be dispersed among several compartments. The system is capable of providing two powerful jets of water at any part of each deck when the watertight and fire-resisting doors are closed. Fire-hydrants may be of the bayonet-joint or screw-connection type, but in modern ships the $2\frac{1}{2}$-in. instantaneous coupling is usually provided. Hoses and branchpipes

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are not usually kept coupled to the hydrants, as in H.M. ships, but are enclosed in glass-fronted cases fitted in prominent positions.

Sprinkler systems.—Automatic sprinkler systems are often provided in passenger and crew spaces. These are usually supplied with water from a gravity tank, supplemented by pumps which automatically come into operation when the tanks are partially empty. One form of automatic operation consists of a soluble plug, fitted in the sprinkler, which melts when the temperature round it reaches a certain degree, thus bringing the sprinkler into operation.

Foam-making installations.—These are fitted in boiler-rooms and may be of the chemical or mechanical types. The foam is distributed by perforated pipes in the bilges.

Smothering-gas or steam systems.—All cargo-spaces are fitted with a system which injects smothering-gas or steam into each space in an emergency. The smothering-gas, usually carbon dioxide, is contained in cylinders fitted in the superstructures forward and aft, and panels are fitted on which are mounted the operating valves and a diagram indicating the various spaces served by the system.

Boiler-rooms are usually fitted with a steam-smothering system, the operating position for which is readily accessible and not easily cut off by fire; a usual position is just outside the entrance to the boiler-room. Unlike the steam-smothering systems in boiler-rooms of H.M. ships, which are fitted high up so as not to be covered in case of flooding, these systems are usually led under the boilers in merchant ships.

Smoke-detecting systems.—These systems are usually fitted in cargo-holds and other spaces which are not easily accessible to patrols. Pipes are led from the compartments concerned to a special cabinet situated in the chartroom, in which a mechanical apparatus indicates when smoke is present in any compartment.

In some systems an audible alarm is also incorporated.

Portable Equipment

Hand extinguishers.—These are generally of two-gallon capacity, and may be of the foam or carbon tetrachloride type, or of the type which discharges water. The latter is the one usually provided; it is of the soda-acid variety and is usually placed near the entrance to each space occupied by passengers, officers, or crew.

In addition, at least two hand foam-extinguishers are supplied to each boiler-room and machinery space for fighting fires involving oil.

Portable emergency power-pumps.—These emergency pumps were supplied to merchant ships during the Second World War for use in the event of damage to the wash-deck service or the pumps supplying it. They are usually petrol-driven, and may be found in ships having all the fire-pumps situated in the engine-room, but where the fixed pumps are well dispersed portable pumps are not normally provided.

Breathing-apparatus.—Suitable types of breathing-apparatus are provided to enable entry into smoke-filled spaces. These may be similar to the Pattern 230 used in H.M. ships, or of the smoke-helmet type.

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Electric drilling machines.—Where electric power is available electric drilling machines are provided as an emergency means of obtaining access to fires through bulkheads, decks, or casings. Oxy-acetylene cutting gear is seldom provided.

Safety-lamps.—These are also provided, and have a minimum burning period of three hours. Tankers carry electric battery-type lamps.

Sand.—In ships using oil as fuel, bins of sand are provided in the boiler-rooms and machinery spaces for soaking up spills of oil.

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CHAPTER XIII

Abandoning Ship, Survival, and Rescue

HOWEVER remote may be the possibility of disaster from fire, collision, stranding or enemy action, seamen should always be prepared to abandon their ship when necessary and take to her boats and life-rafts, either to await rescue or make their own way to safety. Every seaman should also always be ready to rescue the survivors of a ship overtaken by disaster.

Preparation for such eventualities includes not only the provision of the necessary life-saving equipment, but also training the sailor in how to use it. First-class equipment and an intimate knowledge of its use are, however, of little value for abandoning ship or survival adrift without well-thought-out organisation, and those high standards in discipline, leadership and morale which can only be acquired by training.

A classic example of the practical application of these precepts was afforded by the epic voyage, in June, 1923, of the two lifeboats of the s.s. *Trevessa* after she had foundered in the Indian Ocean, in heavy weather midway between Australia and South Africa. The entire crew of 44 officers and men got safely away in the two boats, and 32 of them eventually survived the voyage to safety. The boat commanded by the master, Captain Cecil P. T. Foster, was sailed 1,556 miles to Rodriguez Island, east-north-eastward of Mauritius, in 22½ days, and the boat commanded by the first officer, Mr. James C. Stewart Smith, was sailed 1,747 miles to Mauritius in 25½ days.

The results of inadequate knowledge and training for dealing with such emergencies was exemplified in the Second World War by some tragedies in which, despite the proper provision of life-saving equipment, the foundering of a ship was unnecessarily turned into a major disaster by the loss of most of her survivors through lack of leadership, discipline, or self-control, and ignorance of the use of the life-saving equipment and of how to maintain life when adrift.

A man's chances of being rescued or of reaching safety after shipwreck are good, particularly in temperate and tropical climates, if he is reasonably well equipped and knows what to do. In the Second World War, with its prodigious number of sinkings, the majority of survivors were rescued within three days of the sinking of their ship, and most of these were rescued within a few hours. Those in boats or rafts naturally have a greater chance of survival than those in the water, but there are many known instances of men having been saved after three, four and even five days in the water.

Hope of rescue should, therefore, never be abandoned, and organisation and training must aim at ensuring that the risks run by survivors are reduced as far as possible to those caused by the elements, and that survivors make full use of their opportunities and equipment.

ABANDONING SHIP

Importance of Training

An important but not generally realised aspect of training is its psychological effect of reducing the mental and emotional shock caused by fear. This is due

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partly to familiarity with the procedure or drill, and partly to gaining a knowledge of the dangers to be faced and of the capabilities of the equipment provided. The passengers of a liner, for example, are less likely to panic when ordered in an emergency to their boat stations if they have previously attended several boat drills, because the boat drills will have familiarised them to a certain extent with the procedure and equipment, and imbued them with confidence in the officers and crew of the ship.

Whereas the training of passengers must probably be limited to boat drills, it is essential that as many as possible of the officers and crew of a ship be trained to have a thorough knowledge of her life-saving equipment, its use, and how it works. Lectures and talks are of value in training but they often demand too great a stretch of imagination on the part of the listener, and such training is not nearly so good as the experience gained by drill in actually using the equipment. Whenever possible, therefore, realistic exercises should be planned and carried out. Boats, rafts and floats should be launched, manned and pulled clear of the ship, and men should be taught how to enter the water and swim clear of the ship. In addition men should be taught the relevant first-aid, and also how to conduct themselves in a boat or raft.

Maintenance of Life-saving Equipment

There is always a danger of equipment which is seldom or never used being forgotten or neglected, and then when it is urgently wanted it is found to be in such a bad condition that it is useless. It is most important that the proper upkeep of life-saving equipment should never be neglected, and an officer should therefore be put in charge of all such equipment and an inspection routine be made out to ensure that every item is inspected and tested at regular intervals.

Details of life-saving equipment carried in both warships and merchant ships, and also details of the routine tests to which certain items should be subjected, are given in Chapter VIII of Volume II of this manual. Some important details in regard to its stowage, rigging, inspection and testing are given below.

Life-jackets.—In war one life-jacket is issued to each person, and if inflatable it should be tested daily by inflating it. The jacket may be provided with a battery-operated red light capable of burning for four hours, a red reflector and a whistle ; if so the battery should be tested at regular intervals.

When stored, life-jackets should not be too tightly packed and they should be stowed in places free from oil, paint, grease, and undue heat and moisture. Those made of canvas and kapok should not be exposed to the direct rays of the sun.

Life-jackets should be landed for survey and test at two-yearly intervals.

Carley floats.—The slings, slipping gear and stowages of Carley floats should be inspected regularly to ensure that the float can be launched immediately when required. Common causes of failure in launching these floats are : their slips being rusted up or painted over, their slings being secured together by wire seizings which cannot be cut with a knife, and the actual float being stuck by paint to its stowage.

The equipment of a Carley float should include water and food in hermetically sealed tins, torches, a buoyant battery-operated light, a signalling mirror,

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red distress flares, and, perhaps, smoke projectors, dye-markers, a first-aid kit, a fishing kit, and a tarpaulin painted red or yellow to provide shelter and to catch rainwater. Each float should be fitted with two painters and a lifeline becketed round the sides, and it should also be provided with two rope boarding-ladders, a boathook, a red or yellow flag fitted to a stave, and a set of paddles secured at intervals to the sides of the float by lanyards rove through holes in the grips of the paddles.

Carley floats should not be painted because the weight of successive coats of paint will reduce their buoyancy. If they require touching-up they should be brushed with a water distemper.

Inflatable rafts.—Details of the equipment, maintenance, stowage and tests for these rafts are given in Volume II of this manual.

Floater-nets.—These nets should be stowed in painted canvas covers, and placed where they can easily be cast overboard. When rolled up they should not be stopped or lashed in place, but be secured in their stowages by a strop and toggle, so that when unstowed and cast overboard they can be unrolled without difficulty.

The nets should never be painted, and they should be kept free from grease and oil ; their corks should be inspected periodically to see that they have not been damaged by funnel gases or the weather.

Scramble-nets.—These nets should be securely stowed along the gunwales at places where the freeboard is lowest, but they must be kept well clear of the propellers. They should be so fitted that when unstowed they will hang about one foot clear of the ship's side with their lower edge at least two feet under water when the ship is at light load draught. The net should be spread on spars or battens, fitted at intervals of three feet, and the lower edge should be weighted by a metal tube or bar.

The nets and their spars should never be painted ; they should be protected from funnel gases, oil, grease and dirt by painted canvas covers, and be stowed on chocks clear of the waterways.

Lifelines and jumping ladders.—Both of these should be long enough to reach down the ship's side to the waterline when the ship is at light load draught and listed 15 degrees to the opposite side. Except in ships with low freeboard the lifelines should be knotted or fitted with standing Turk's heads at intervals of a few feet to provide handholds and footholds, and when practicable they should be rigged over chocks so that they hang clear of the ship's side. Ladders should be stowed rolled up and secured by strops and toggles to the bulwarks or guardrails, clear of the deck. Neither lifelines nor ladders should be painted, and they should be protected from grease, oil and funnel gases.

Lifeboats.—Details of the fittings and equipment of a merchant ship's lifeboat are given in Volume II of this manual.

The falls, slings, blocks, hooks, davits, winches and luffing or turning-out arrangements should be very carefully maintained. Common causes of accident or failure when trying to launch a lifeboat are failure of the disengaging gear, parting of the falls, and the davits being jammed by rust or paint. Every opportunity should be taken to test the launching arrangements of each boat at regular intervals.

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Attention should be paid to the hull planking of wooden boats to ensure that the seams are watertight. In particularly hot and dry weather every opportunity should be taken to wet the boats, either by spraying or flooding them, or by exposing them to the dew at night, to ensure that the strakes do not become dry enough to shrink and open their seams.

Particular attention should be paid to the sails and the standing and running rigging of boats equipped for sailing. In humid climates sails will rot in their covers unless they are frequently spread and dried on a dry, sunny day.

Batteries of boats' electrical and wireless equipment should be tested at regular and frequent intervals and be replaced or recharged if necessary. This is an important item of routine maintenance which is often overlooked or neglected. The functioning or failure of a light or a radio set in a crisis may make all the difference between rescue and disaster.

Pyrotechnics.—All propellants and explosives, such as cordite and gunpowder, deteriorate with age, and this deterioration is accelerated if they are not kept in a cool and dry atmosphere. A maximum age of about five years is laid down for fireworks stored under the best conditions, after which they are destroyed.

Deterioration, as well as affecting the functioning of a firework, may also make it dangerous to handle or liable to spontaneous combustion. All fireworks in stowages other than magazines or special tanks are subjected to considerable changes of temperature, particularly in ships plying between temperate climates and the tropics, and they should therefore be changed at yearly intervals and landed for test; failure to do this has resulted in many unfortunate accidents.

Food and water.—These are usually provided in hermetically sealed tins to a scale commensurate with the number of persons the boat or raft is designed to carry. Food tins should be examined periodically for signs of deterioration, such as rust causing pinpricks which allow air into the tin, undue bulging caused by decomposition of the food inside the tin, dents which may prevent the tin from being opened, and cracks. If the water is carried in barricoes it should be changed weekly, otherwise it will become foul; the barricoes should be flushed out occasionally with a solution of bicarbonate of soda and water to keep them sweet and fresh; the bungs should be tightly fitting but easily removed. If the water is stowed in galvanised iron tanks their inside surfaces should be brushed with a wash consisting of equal parts of cement and lime mixed with water.

Miscellaneous equipment.—Lamps should be kept trimmed and filled with oil which should be changed occasionally. Matches should be kept in a waterproof container, preferably with the distress flares. Wire ropes and unpainted metal fittings should be rubbed over with fish-oil. Two plugs should be provided for each plug-hole, and they should be secured to the boat with a lanyard; the positions of plug-holes should be indicated by a tallied arrow painted on the thwart, bench or side of the boat above the hole.

All gear should be secured with light stops or strops and toggles.

Importance of Adequate Clothing

Experience has proved that in both cold and tropical climates people stand a better chance of survival when fully clothed and wearing boots or shoes than when they are naked or only partly clothed. In addition to keeping a man

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warm, clothing protects him from wind, rain, spray and the heat of the sun's rays. Warm and waterproof clothing, such as woollens, oilskins and greatcoats, is the best, and if time and space admit, these may be supplemented by blankets, tarpaulins and a change of clothing, particularly of socks (in the Second World War it was the practice when in dangerous waters for everyone to have ready at hand a small waterproof bag containing a change of warm underclothes and a few small personal necessities). Clothing is buoyant because of the air trapped inside it, and until it is absolutely saturated it will help to keep a swimmer afloat for at least a quarter of an hour. The standard life-jacket has sufficient buoyancy to support a fully-clothed swimmer for an indefinite time.

Boats' Provisions

The results of experience gained in the Second World War, and of experiments conducted after it, have provided a basis for determining the best kind and quantities of rations to be provided for life-saving craft.

The space available for their stowage being restricted, the provisions must be condensed and compact and their quantity must be limited. They must be highly nutritious, easily digestible, and in the process of digestion and excretion they must waste as little as possible of the water stored in the body. Rations for life-saving craft are therefore of a special nature and comprise such things as boiled sweets, special toffee made with fats, sweetened condensed milk, biscuits of a fatty nature, and malted-milk tablets. It will be noticed that the basis of these foods is fat, sugar or starch, and that no salty foods or foods with a protein basis are included because they are not completely absorbed in digestion and the excretion of their waste products uses water which the body can ill afford to lose. When it is possible or desirable to augment the normal rations of life-saving craft, foods which contain fat or starch, such as butter, sugar, potatoes, glucose, biscuits, oatmeal and chocolate, should therefore be chosen in preference to foods such as pressed-beef, tinned-salmon, poultry, eggs, tongue, cheese, peas and beans.

Water of any description whether from rain, or a tap, or distilled is liable to become foul after a few days, and if it is stored in barricoes or tanks it should be changed at least once a week. If, however, it is specially treated and put in hermetically sealed containers it will keep sweet and pure indefinitely, and it is therefore present-day practice to provide water in sealed cans or plastic bottles.

Experience during the Second World War showed that only very exceptionally were survivors adrift for longer than three days, and that most were rescued well within this period. From four to five days has therefore been selected as the period on which to base the quantity of rations for life-saving craft.

Of the limited stowage space available more is allocated to water than to food because water is more necessary for survival than food; a man can survive 30 days or more without food if he is given sufficient water. The value of food, however, should not be underrated, because it provides a man with the necessary energy to keep his body functioning and so keeps him healthy; it also helps to keep his body warm and provides the extra energy required to keep the blood in circulation. In cold climates food is particularly important, but in both cold and hot climates men should be encouraged to eat their ration

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even though they have no appetite. A man will usually require more water in a hot climate than in a cold one because in hot weather he loses so much more moisture from evaporation and sweating.

Experience and experiment have shown that a man requires 17 ounces of water a day, and 1,200 calories of food, to keep him healthy; these are minimum quantities and the water ration should be augmented whenever possible by rainwater or distilled water. A man will not necessarily die if given lesser quantities, but his health will suffer and he will weaken considerably. Experience has shown that if supplies of food and water are very limited it is better to hand out the authorised daily ration until it is exhausted than to issue a reduced ration over a longer period.

Examples of daily rations found by actual experience to be adequate are given below as a general guide.

FULL RATION (*desirable if space allows*)

	Amount	*Calorific Value*
Water	1½ pints	—
Boiled sweets	3½ oz.	400
Toffee (30% fat)	3½ oz.	500
Sweetened condensed milk ...	3½ oz.	350
Biscuits (fatty content) ...	3½ oz.	480
	Total	1,730 calories

REDUCED RATION (*minimum desirable*)

	Amount	*Calorific Value*
Water	17 oz.	—
Boiled Sweets	3½ oz.	400
Toffee (30% fat)	3½ oz.	500
Sweetened condensed milk ...	3½ oz.	350
	Total	1,250 calories

MINIMUM RATION (*minimum essential to sustain life*)

	Amount	*Calorific Value*
Water	14 oz.	—
Boiled sweets	5¼ oz.	600
	Total	600 calories

Note: 20 oz. go to a pint of water.

If time allows everyone should take a good drink of water before abandoning ship, and no water ration should be issued for the first 24 hours (except to sick or wounded men) because it will probably be wasted as urine. Vomiting from seasickness should, if possible, be prevented because all the valuable water in the stomach is thereby lost; the remedy supplied for seasickness should therefore be distributed at the first opportunity after manning the boat and everyone should take it, even those who think they are immune from the malady.

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Organisation for Abandoning Ship

The signals for abandon-ship stations in merchant ships consist usually of continuous blasts on the siren, the ringing of electrically operated alarm bells throughout the ship, and perhaps the order " All hands to boat stations " broadcast on loudspeakers. In the Royal Navy the signal is the order " Hands to emergency stations " broadcast on loudspeakers. The word " emergency " is used here to avoid any possibility of confusion with the final order " Abandon ship, " which is only given after all available boats and rafts have been lowered and manned, and when the ship is about to founder.

The organisation for abandon-ship stations is based on the assumption that the ship will founder on an even keel, and that there will be sufficient time for all boats and life-rafts to be lowered and manned. It is quite possible, however, that because of lack of time, damage to boats or their lowering gear, or the listing of the ship, it will not be possible to lower or man all the boats and life-rafts with which the ship is equipped. The organisation must therefore cover these eventualities to ensure that all possible boats and life-rafts are lowered, safely manned, and got clear of the ship in the time available, and that order is maintained among those remaining on board and all possible provision made for their survival.

In a warship this is a comparatively simple matter, but in passenger ships, where the passengers may be of many nationalities and unused to discipline or self-control, it may necessitate arming the officers in charge of boat stations and using force to check any signs of panic or insubordination. In such circumstances the main object should be to get as many people as possible away from the ship in safety, and to this end the unco-operative individual must be sacrificed for the sake of the majority.

An officer should be detailed in charge of each boat and life-raft, together with a second-in-command and at least two seamen with a knowledge of boat-handling ; in a crowded boat with a mixed crew it may be necessary for the officer-in-charge to be armed. Arrangements should be made to inform those in charge of boats of the ship's position, whether her distress signals have been answered, the likelihood of early rescue, the course and distance to the nearest land or shipping lane, and any other information of navigational or operational importance. If it is likely that the boats will have to sail a considerable distance to safety each should, if possible, be equipped with a chart, sextant, chronometer, nautical almanac, nautical tables, dividers, and a ruler and pencil.

Stations.—The main object of detailing each person to a specific abandon-ship station is to ensure that all on board are divided into easily handled groups around the weather decks, whence they can be detailed to man the available boats and life-rafts before or after they have been lowered into the water. It also ensures that everyone assembles in an orderly manner and is kept clear of those of the crew whose duty it is to clear away and lower the boats and life-rafts. In ships carrying many persons, passenger liners for example, a specific route from between decks to the weather decks is detailed for each group, to avoid, as far as possible, any one route being overcrowded or jammed.

In merchant ships the people are usually assembled in groups on the boat deck, or when possible on the deck immediately below it, abreast the boat for which they are detailed.

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In warships, where the boats are usually grouped amidships, officers and men are not usually detailed to specific boats, but are grouped around the upper and forecastle decks, whence they are detailed to man the available boats and life-rafts as they are prepared and lowered by men specifically detailed beforehand for this duty.

Remarks on Abandoning Ship

Life-rafts should be cast or dropped overboard, but remain secured to the ship by a line until their crews have manned them over the ship's side. Boats should not be kept alongside longer than is absolutely necessary owing to the risk of their being damaged by the seas against the ship's side, or being capsized or swamped through fouling falls or lifelines or by people jumping into them. They should therefore be lowered with as many people in them as the state of the sea allows, and as soon as they are slipped or unhooked they should get clear of the ship and lie off to embark the remainder of their complement from the water.

As soon as the boats and life-rafts have embarked their full complements they should be pulled or paddled two to three hundred yards clear of the ship and remain there in as compact a group as possible until the ship founders. Except in a rough sea, it is a good plan to secure boats and rafts to each other by their painters. Individuals still swimming can then be picked up, or be grouped together and provided with any floating wreckage available, such as spars, planks or gratings from the foundered ship. The complements of boats and life-rafts can then be adjusted to their respective capacities, or to fulfil special requirements, such as the care of the injured, wounded, or infirm.

If there are still any persons on board after all boats and rafts have been manned and got away, they should abandon their ship and swim at least 100 yards clear to avoid being sucked down or entangled in her rigging as she founders, and to avoid being struck by any wreckage which may subsequently rise to the surface with considerable force. When abandoning ship the following points should be borne in mind :—

(i) Whenever possible lower yourself into the water on a line. If you cannot lower yourself, jump into the water feet first ; never dive in head first. When wearing a life-jacket avoid jumping from heights of above ten feet, because the jacket may be jerked violently upward on impact with the water and so stun you or break your neck ; if jumping from higher than ten feet is unavoidable, cross your arms with your hands on your shoulders to keep the jacket down as you enter the water.

(ii) If the ship is drifting it is better to leave her over the weather side, otherwise it may be difficult to swim clear, but jump well clear of the side and swim quickly away to avoid being washed back on board by a sea.

(iii) If possible, always avoid any oil fuel floating on the surface, either by swimming below it to clear water or by swimming through it with your head held high and your mouth shut.

(iv) If the ship is listed leave her over the bows or stern, if possible. If you jump from the high side you may strike the bilge keel, or propellers, or injure your hands and feet on barnacles on the exposed part of her

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bottom, and if you leave by the low side you may be struck by the superstructure, masts, or funnels if the ship capsizes before you can swim clear.

(v) Burning oil floating on the surface can be negotiated in the following manner: remove your life-jacket and any heavy clothing; take a deep breath and jump in feet first; swim under water for as long as possible, then spring above the flames and take another breath while pushing away the flames with a breast stroke; then sink and swim under water again. Men have safely negotiated a patch of more than 200 yards of burning oil in this manner.

When clear of the ship swimmers should cling to any floating wreckage available, and form themselves into compact groups to provide mutual support and encouragement. When possible, swimmers in a group should rope themselves together, preferably in a circle, and should avoid undue exertion. A group of swimmers also stands a better chance of being sighted and rescued than do individuals.

Subsequent action of the survivors must depend on circumstances such as the weather, the position in which the ship foundered, and the proximity or otherwise of shipping. If, for example, the ship foundered far from land in a well-frequented sea lane, and if her distress signals had been answered, it would be best for the boats and life-rafts to remain grouped together as near as possible to the position where their ship foundered. If, however, all the survivors are in boats, and a hospitable shore is close at hand to leeward, it may be best to sail in company to the land.

SURVIVAL

The qualities which are essential to the survival of the crews of boats or rafts when adrift in the open sea are discipline, confidence, cheerfulness, willingness, and a determination to win through, and the man in charge must be a good leader.

The most exacting task is that of whoever is in charge, because in addition to looking after the safety of his craft, he must inspire the crew with confidence, both in himself and themselves, maintain strict but sympathetic discipline and be ready to enforce it vigorously if necessary, and always maintain a cheerful and optimistic bearing. He should arrange for each of the crew to be given a specific duty, and should work out a daily routine and see that it is strictly carried out. He must also take charge of the rations and supervise their issue, and ensure that the sick and wounded are looked after.

Captain Foster of the *Trevessa* wrote in the account of his voyage: " I used to wonder at the time, and I have often wondered since, which was harder—to be one of the crew who had merely to struggle along day after day, relying absolutely on those who were using their skill and knowledge to bring the boat to safety, or to be one of those who had the responsibility of bringing the men through." Captain Foster, however, was a very modest man, and there can be little doubt that the leader's is the harder task.

The following remarks on survival adrift are based on experience and experiment, and although based chiefly on experiences of survival in a ship's open lifeboat they can be applied to survival in any type of life-saving craft.

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Remarks on Survival when Adrift

Seasickness

It is most important that seasickness should be prevented if possible, because vomiting empties the stomach of its valuable liquid which would normally be absorbed into the body. As soon as possible after abandoning ship, therefore, the seasickness remedy should be distributed and be taken by each of the crew. Everyone should take the remedy for the first 48 hours, because even the hardiest of sailors can be upset by the motion of a boat; thereafter it need only be taken by those who are still feeling queasy.

Aid to Swimmers

If the boat is not filled to capacity any men swimming about or holding on to floats should be picked up; when picking them up care should be taken to keep the boat on an even keel and if possible they should therefore be hauled aboard over the bows or the quarters. If the boat is filled to capacity, however, no attempt should be made to pick others up, because this will probably result in capsizing the boat or in sinking her. In these circumstances it would be stupid to risk twenty or more lives for the sake of one or two.

Distribution of the Crew

The seamen should be divided fairly evenly between the bow sheets and the stern sheets, as there they will be best placed for handling the boat and maintaining a lookout. An officer or other responsible person should be put in charge of the forward party, and the afterguard should include the Second-in-Command and any other officers who can help in the handling of the boat and in general supervision. The remainder of the crew should be stationed amidships, together with any sick or wounded, but a clear space should be left for baling.

Recovery of Flotsam

If it is unlikely that the boats will be picked up soon every opportunity should be taken while in the area where the ship foundered of recovering any articles which might be useful, either while adrift or if cast ashore. Extra clothing is of great value, and any bodies should be stripped of their clothing and belongings; identity discs and personal valuables should be put to one side, and the clothing be distributed among the survivors. Barricoes or other containers, and rope, twine and scraps of metal, may prove invaluable later on.

Weapons

Any weapons such as axes and knives, particularly sheath knives, and any potential weapons such as belaying pins and crutches, should be passed aft into the custody of the afterguard. Experience has shown that, unless the period adrift will be short, this is a wise precaution to take, because men often become light-headed, delirious, irresponsible or even vicious under the privations and hardships of being adrift.

Distress Signals

Because their number is limited all distress signals should be in the custody of the afterguard, and they should be used only on the direct order of the officer in charge of the boat. When adrift for some time men often imagine rescue is at hand, and they may then needlessly expend a valuable signal.

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Routine and Duties

When the crew have been distributed and have settled down they should be divided into three or four watches, and a simple routine should be devised. Each member should if possible be allotted a task, no matter how trivial, both to keep the boat shipshape and to occupy his mind. Such duties should include lookouts, steering, baling, keeping the bilges dry, cleaning out the boat, taking care of the sick and wounded, and assisting in the issue of rations.

Stowage, Custody and Issue of the Rations

As much of the rations as possible should be stowed in the stern sheets, or in the after part of the midship part of the boat, where they are under the direct care and supervision of the afterguard. This precaution may not be necessary if the period adrift is likely to be short, but is essential if rescue is unlikely for some days.

An officer or other responsible person should be put in charge of the distribution of the rations. He should keep a record of issues and of the stocks remaining, particularly of water, so that the officer in charge of the boat can assess the situation at any time.

The rations should be issued punctually at routine times; this is important, particularly when likely to be adrift for some days, because irregular or unpunctual issues under such conditions are very irritating. Both food and water should be issued three times a day, at sunrise, noon and sunset, and it is important that they should be issued as openly as possible, so that each person knows he is getting his proper ration and that nobody is getting more than his fair share. It is a good plan when issuing the rations to call up each person from a roster, and everyone should if possible have his own drinking cup or tin; this allows each man to drink his water ration in his own way and in his own time, and so avoids the irritation of having to swallow the water ration quickly or that of having to wait in suspense while someone slowly sips his.

If the period adrift is likely to be long no water ration should be issued in the first 24 hours, because it will then be wasted as urine without doing much good.

No individuals should be given an extra water ration especially if they have aggravated their thirst by drinking sea water, but an extra ration may be given to the sick and wounded if the situation allows. Each man should make the most of his ration of water by keeping it in his mouth for a long time and gargling with it before finally swallowing it.

To make the best of biscuits they should be broken up and the pieces put in the pockets for nibbling occasionally throughout the day; they can be soaked in the water ration if desired. Condensed milk can be spread on biscuits or mixed with water, but it is probably best if taken by itself one hour before the water ration is issued.

All food should be sucked, chewed, or eaten slowly.

Any fish or birds should be eaten, cooked or raw, as soon as possible after they are caught, particularly when in the tropics; no fish or birds should be eaten, however, unless there is plenty of water to drink, because digesting them uses up a lot of the body's water.

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Protection and Comfort

As soon as the crew are settled in their places every practicable means should be adopted for protecting them from the weather and making them as comfortable as possible. The boat should be kept dry, and baling and drying out the bilges should be regarded as one of the most important duties. Life-jackets of the Ministry of Transport type are usually an encumbrance when worn in a boat, and unless there is a likelihood of falling overboard or of the boat capsizing, they can be removed and used as cushions over the bottom boards and serve to protect the men from chafe and keep them clear of any bilge-water. No one should be allowed to urinate into the bilges, and standing up to pass water over the side may be dangerous ; some such vessel as a tobacco tin should be used for this purpose. After the first 24 hours men will only want to urinate very infrequently.

In cold weather it is essential to keep everyone as warm and dry as possible. Tarpaulins or other covers should be rigged across the boat from gunwale to gunwale, particularly over the bow sheets, and every means should be taken to keep out wind, rain and spray. Wet clothing should not be removed, it will soon dry if the man is kept warm. Those not on lookout or steering duties should huddle together in the bottom of the boat for warmth, and cover themselves with any spare clothing they have been able to salvage.

It is particularly important to keep the hands and feet as warm and dry as possible, and to keep the blood circulating in them. Simple exercises should be devised for clenching and stretching the fingers, flexing the wrists, bending and stretching the neck, curling and stretching the toes, flexing the ankles, and moving the main joints of the body, and they should be carried out at regular and frequent intervals.

In very cold weather the men should keep their hands under their armpits, and a very effective way of keeping their feet warm is for the men to arrange themselves so that the feet of one man are resting on the bare flesh of another's stomach, within his clothing.

The life-rafts of H.M. ships are provided with a tent which can be made almost airtight ; the heat of the bodies and breath of the men then very soon produce a warm, humid atmosphere of at least 70°F within the tent, and this provides a most effective protection against cold. In open boats every attempt should therefore be made to exclude air and to make the boat as snug as possible.

In hot weather everyone must keep as cool as possible during the day, and avoid any exertion which will make him hot and cause him to sweat and so lose some of the valuable water in his body. Tarpaulins, the boat's cover, or her sails should be used as awnings to keep the sun off, and they should be rigged so that any breeze can pass under them and into the boat. Frequently wetting the awnings will help to keep the boat cool, and wetting one's shirt and keeping it damp during the day will keep the body cool. All domestic work should be completed before the day gets hot, and from then until the evening those not on duty should rest and relax as much as possible so as to conserve their energy and keep cool.

Sunburn and glare can be dangerous, even on cloudy days, because in a boat you are subjected to the reflected rays of the sun from the surface of the sea as well as to its direct rays. Exposure to the sun should be avoided as much as possible ; anyone on duty outside the shade of the awning should keep him-

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self entirely covered, a towel or shirt being worn loosely over the head " burnous" fashion to protect the neck, mouth and nose from sunburn, and the eyes from glare. Fuel oil or greasy ointments will not protect the skin from sunburn ; keeping well covered and using the special preparation supplied in the first-aid kit are the best precautions against sunburn. Any kind of face ointment rubbed over the lips and round the eyes is a good preventive against cracked and dry skin, and toothpaste rubbed round the teeth and gums is most refreshing when the mouth is parched.

Bathing over the side should not be allowed because it uses up valuable energy and does not keep the body cool as well as damp clothing will ; in addition there may be sharks about.

In the evening, just before sunset, all clothing should be dried, and the boat should be dried out as thoroughly as possible. Tropical nights can be very cold, and before dark the awnings should be frapped down to make the boat as snug as possible, but all the air should not of course be shut out.

Navigation and Sailing

The decision whether to remain in the area where the ship foundered or to endeavour to reach land depends on many circumstances, but experience has shown that unless there are strong reasons to the contrary it is usually best to try to keep as near as possible to the place where the ship sank. Before the ship sank a distress signal giving her position would probably have been broadcast, and even if no reply had been received it does not necessarily mean that the signal had not been received. Any search for survivors is usually based on the last known position, course and speed of the ship, and it will usually start from the position in which she is assumed to have foundered. Even if no distress signals had been broadcast from the ship, wireless signals from the sets with which most lifeboats are nowadays equipped should guide rescue ships and aircraft to them.

If it is decided to remain where the ship foundered the sea anchor should be streamed, and a small mizzen should be hoisted to keep the boat head to wind and sea. If the weather is too rough for this a small headsail should be hoisted and the sea anchor should be streamed aft to act as a drogue, and the boat should then be sailed as slowly as possible before wind and sea.

When running before heavy seas they can usually be prevented from breaking and pooping the boat by slinging over each quarter a cigarette tin which is kept filled with oil and has a small hole punctured in it.

If it is decided to make for land it should be borne in mind that the average lifeboat cannot sail near the wind, and may ship a good deal of water when beating or on a close reach. A course should therefore be laid which will keep the prevailing wind abaft the beam, preferably between the quarter and abeam, even though it entails sailing a longer distance. If the boat is becalmed the sails should be kept hoisted to attract attention.

At night, if the sky is clear, course should be set by the stars near the horizon, using the boat's compass as a general check. With only an elementary knowledge of the stars and their progression round the sky a surprisingly accurate course can be steered in this way.

When under sail at least two helmsmen should always be on watch, one to steer and the other to support him against the movement of the boat and to keep him awake and alert. The utmost care should be taken of the sails, because

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the chances of survival will probably depend on them; they should not be used as covers or awnings, or to catch rainwater.

Sails should always be lowered when about to collect rainwater, because everyone is then preoccupied with the main job of catching the rain.

Oars should only be used to pull clear of the ship, manœuvre the boat into the path of a rainstorm, avoid a navigational danger, or pull ashore. Any distance gained in the open sea by pulling is more than offset by the consequent fatigue of the crew, who must conserve their energy as much as possible. Oars may be used to give the crew exercise or to alleviate boredom, but only if the crew are well fed and in good fettle.

Rainwater

Every opportunity should be taken of supplementing the water ration by catching rainwater. The tarpaulins, boat's cover, and the sails when not sailing, should be used for this purpose and be supplemented by any waterproof clothing such as oilskins. They may all be caked with salt from evaporated spray, and if so they should be washed in the sea before being used, otherwise the rainwater will be made very brackish. Anyone can catch an appreciable amount of rainwater by means of a tin, or some other stiff but pliable material, cut and bent to fit round the jaws and chin in the form of a chute; it is then held close up to the chin with a mug beneath it during a rainstorm, and a surprising amount of water can be collected in this way. Water can also be caught by spreading out a pocket handkerchief and then wringing it out into a mug.

All the rainwater collected by tarpaulins should be stored for general use in any containers available; if any is then left over it should be distributed equally among the crew as an extra ration. If the normal water ration is provided in sealed tins the rainwater should be issued first, because it will not keep sweet for as long as the " tinned " water.

Sea Water and Urine

On no account should anyone drink sea water or even rinse out his mouth with it; anyone attempting to do so should be forcibly restrained. Not only does sea water aggravate thirst, but it is very harmful, causing madness and death in a short time.

Urine should never be drunk. It is full of the waste products of the body and it is therefore useless and harmful to drink it. It is useful, however, when applied externally as an antidote for the stings of jellyfish or other mildly poisonous marine creatures.

Keeping a Log

The officer in charge should if possible keep some sort of log in which he should record the names of all on board, routine matters such as the issue of rations, the weather and the course, and anything else of interest.

Miscellaneous

Cheerfulness and optimism are invaluable. Many accounts of survivors mention that a sing-song in the evenings, and talks and reminiscences, go far to alleviate the hardships and keep up the spirits of survivors. Smoking when under the worst conditions is apt to increase thirst, but under average conditions

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an occasional cigarette or pipe is a great comfort. Economy in the use of matches is important, and the stocks of matches should be in the custody of the afterguard.

Sharks and other large fish may approach the boat out of curiosity, and they sometimes even rub themselves on the bottom of the boat to get rid of their sea-lice. Usually they intend no harm unless they are annoyed or injured, and they can usually be scared away by splashing the water with oars or paddles. On no account should any attempt be made to catch or injure them because they may then become dangerous. Never allow offal or any blood to be thrown over the side when sharks are in the vicinity.

Small fish and turtles may often be found under a stationery boat or raft; they go there for the shade it affords them from the sun, and if fishing tackle is available it should be fairly easy to catch them. Flying fish may also land in the boat and they make very good eating. Attention is drawn to the warning on page 277, against eating fish or birds unless the crew are well supplied with water.

First-aid

Equipment and its Use

Most life-saving craft carry a first-aid kit and the following is typical of what is usually included.

Drugs:

aspirin tablets, or codeine-compound tablets;
Omnopon (gr. $\frac{2}{3}$) in tubunic self-injecting ampoules (=morphine gr. $\frac{1}{3}$);
tablets of morphine hydrochloride (gr. $\frac{1}{2}$);
quinine tablets;
a sulphonamide preparation, or acriflavine solution, $\frac{1}{100}$.

Dressings, etc.:

field and shell dressings;
elastic adhesive dressings, 3 in. wide;
triangular and unbleached calico bandages, 6 in. wide;
small packets of gauze, cut to 4 in. × 4 in.;
waterproof material;
cotton wool in 1 oz. packets;
Gooch splinting (assorted sizes);
vaseline;
safety pins and blunt-pointed scissors;
an unbreakable 2 oz. measure (graduated).

Aspirin or codeine tablets should be given to relieve headaches and mild pain resulting from injuries such as sprains, bruises, minor wounds and jellyfish stings. The dose should be two or three tablets at a time, and if they are chewed before swallowing them they will act more quickly than if swallowed whole.

Omnopon or morphine is given to relieve severe pain and to promote sleep, and to offset the effects of severe shock or to quieten delirious men. It should not be given to unconscious or semi-conscious men.

The morphine tablets are handier to use than the omnopon ampoules, but they require longer to take effect—half an hour as against 10 minutes—and

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morphia taken by mouth is apt to cause vomiting. The dose is one tablet or one ampoule at a time, repeated if necessary at intervals of between four and six hours.

Quinine tablets are used for feverish cases. The dose is one tablet taken every four hours.

A sulphonamide preparation and an acriflavine solution are provided for treating burns, wounds, abrasions and open sores. Instructions in their general use are given below.

The dressings and other equipment are used for binding up wounds, covering burns and sores, and bandaging broken limbs.

Treatment of Wounds

To stop profuse bleeding apply an extra large dressing and bandage it tightly over the wound ; a limb which is bleeding freely should be raised above the body until the bleeding stops. Having dressed the wound do not remove the dressing again ; if blood soaks through the bandage put some more wool over the dressing and apply another bandage on top of that. If a man has lost much blood he should be given a drink of water, and his water ration should be increased for the first 24 hours.

The general treatment for other wounds is cleanliness and rest. Conditions for attending the wounded in a boat are difficult and the best course is first to clean the wound thoroughly, apply one of the germicides and a dressing, and then bandage it up securely and leave it alone until it can be attended to under better conditions.

To dress a wound in the first instance remove any clothing near it, cutting it away if necessary ; take care not to touch the wound with your fingers, because they are always contaminated with germs and may cause blood-poisoning, and do not try to remove any pieces of metal or bone unless they are lying loose in the wound. Next wash or douche the wound gently with clean sea water and then apply the germicide as directed by the instructions printed on its container. Next apply a dressing, taking care not to touch the part of the dressing which will be next the wound ; a field or shell dressing is the easiest to apply, but if one is not available place over the wound a piece of gauze soaked in diluted acriflavine solution or dusted with sulphonamide powder. Finally, cover the dressing with cotton wool, put a piece of waterproof material over the wool, and then bandage it firmly in place.

Treatment of Broken Bones

No unqualified person should attempt to re-set a broken limb, because he may well do more harm than good ; the injured man should be kept warm, comfortable and free from pain until he is rescued, when the limb can be reset by a doctor.

Clothing over the broken limb should not be removed unless there is an adjacent wound which must first be dressed, or unless it is a compound fracture with the bones protruding from the skin, in which case the broken skin must be dressed.

The broken limb should be put in splints as directed below :—

First place it in as natural a position as is possible without causing undue pain. Then select a piece or pieces of splinting large enough to wrap round the limb and to extend well above and below the fracture. Wrap the limb

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with a layer of cotton wool, then place the splinting over the wool and secure it firmly but not too tightly in place with bandages in whatever position gives the greatest comfort. If parts of the limb below the splint swell up, the bandage is too tight and must be loosened.

Give the man an injection of omnopon, or a tablet of morphine, and wedge him firmly between two other men to save him from any motion of the boat.

Treatment of Burns, Scalds, Sun-blisters and Rope-burns

A burn should not be touched with the fingers, and no attempt should be made to prick any blister or to clean any oil fuel off a burn.

Burns on the hands and feet, including rope-burns of the palms of the hands, should first be washed with sea water, and a solution of acriflavine diluted with sea water should be poured over them.

The sulphonamide preparation should then be applied to the burn, and the burn then be covered with a layer of gauze, then one of wool, and then one of waterproof material, and finally it should be bandaged.

The man may be given an injection of omnopon or a morphine tablet.

Treatment of Shock

Shock is always likely to occur after any severe wound, burn, scald, blast, or fracture of a bone. The symptoms are paleness and coldness, probably accompanied by restlessness and breathing of a sighing nature. The man may or may not be in pain, and he may be abnormally cheerful, particularly if he has lost much blood.

To treat a man for shock first lay him flat, if possible, and get his head lower than his body by placing a life-jacket or cushion under the middle of his back to assist the flow of blood to his head. Then raise his legs above his body by propping his feet on a thwart or the gunwale, or by drawing his feet up to his buttocks. Keep him warm by covering him with coats or blankets. Give him a drink of water, and also an injection of omnopon or a morphine tablet ; the injection or tablet should not be repeated for four hours.

Treatment of the Apparently Drowned

The treatment consists of artificial respiration and must be begun immediately the man is rescued ; no time must be lost, even to loosen the clothing—and it must be continued uninterruptedly for at least an hour. In some cases life has been restored after two or more hours of continuous work.

First place the man belly downward on the bottom boards, or other flat surface, with his head turned to one side and his arms laid forward, as shown in Fig. 79 (i). Then kneel beside the man with your knees abreast his buttocks, and place your hands, palms down, on the small of his back. Your wrists and thumbs should be nearly touching each other, and your fingers should cover the man's loins on each side, but not be spread out.

Now, with your arms straight, swing slowly forward, pivoting on your knees, until your thighs and arms are perpendicular and the weight of your body is bearing on the small of the man's back, as shown in Fig. 79 (ii). This movement forces the contents of the man's stomach up against his diaphragm, which rises and so makes him breathe out and thus expel any water which may be in his lungs or windpipe.

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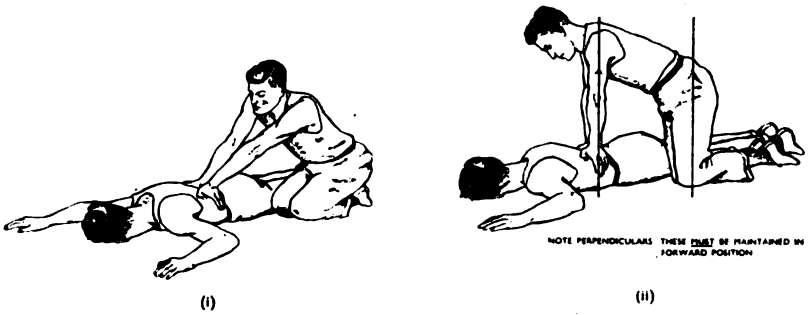

Fig. 79. Resuscitation of the apparently drowned

Then swing slowly back to your original position, thus removing your weight off the man and allowing his stomach to return to its normal position. With the pressure of the stomach thus removed from the diaphragm, the latter will move back and so make the man breathe in.

The two movements should occupy about five seconds, two for the first and three for the second, so that the cycle is repeated about twelve times a minute. In each cycle the pressure should be applied and relaxed as follows :—

first second—increasing pressure ;
second second—pressure steady ;
third second—decreasing pressure ;
fourth and fifth seconds—pressure relaxed, operator resting.

This treatment should be continued until the man again breathes naturally, or until he is obviously dead.

The man must be kept as warm as possible, both during artificial respiration and after he has come to, until he is fully recovered. He must not be turned on his back, or given a drink, until his breathing is normal and he is fully conscious. Afterwards he may be encouraged to sleep, while lying on his side and warmly covered, but he must be watched carefully for some time to ensure that his breathing does not fail again.

Signs of Death

A man can be assumed to be dead if his pulse cannot be felt at his wrist or deep in his neck, and if the pupil of each eye (the black circular area in the centre of the iris, or coloured part) is very large and does not alter in size when a torch or bright sunlight is shone into it. After death the pupil is so large that it occupies most of the area normally occupied by the iris.

Common Ailments in Lifeboats

A number of ailments may develop from long exposure to sea water, sun, heat and cold, and as a result of shortage of water.

Dry mouth is a common complaint, but it can be relieved, as described earlier, by keeping the drinking water ration in the mouth and gargling. Some relief can also be obtained by sucking buttons or a piece of metal such as a coin, or by chewing gum, or greasing the inside of the mouth with butter-fat.

Cracked and parched lips should be smeared with vaseline.

Cracked skin, caused by exposure to sun or the salt in sea water, may be prevented by painting on special anti-sunburn lotion, or by rubbing on vaseline.

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Salt-water burns or boils should not be squeezed or pricked, and if they burst the matter should not be squeezed out of them. Large, angry-looking boils should be painted with a solution of one part of acriflavine to nine parts of sea water, and then be covered with a dressing. If the boils are small, however, and do not seem to be coming to a head, they can be left exposed to the air after applying the solution.

For inflammation of the eyes, from flash-burns, fuel-oil, or sun glare, for example, the upper and lower eyelids should be smeared with vaseline and a small dab of it be applied to the outer corner of the eye itself. If the eyes are very painful and bloodshot a piece of wool should be lightly applied and the eyes bandaged.

Fever.—Anyone showing symptoms of fever, such as a flushed face, general aching, sweating, and shivering, especially in hot weather, may be given one tablet of quinine, or two tablets of aspirin, every four hours. Men with fever may become restless or light-headed and not altogether accountable for what they may do or say, but they will not be violent. They should be humoured so that they can be easily restrained, and kept contented. Care must be taken to prevent them from going overboard through not realising where they are or what they are doing.

Delirium usually results from drinking sea water, and a man suffering from it may become aggressive and violent. It is useless to try to reason with a delirious man, and the best treatment is to tie him up and give him injections of omnopon every four hours until he either calms down, recovers, or dies.

Vomiting may be due to seasickness, or to swallowing fuel oil or sea water; it is unlikely to continue for very long. After severe vomiting the patient should lie down, be kept warm with coats or blankets, and given extra water if necessary.

Constipation.—Only very infrequent action of the bowels can be expected when taking little food; no treatment is needed for this condition—in fact, laxatives will do harm.

Diarrhœa.—A tablet of morphine should be given by mouth every four hours until the loose motions are checked. Should the man become very drowsy the morphine should be stopped.

Difficulty in passing urine may occur, and the bladder may feel uncomfortably full; dangling the hands in the sea will help urination, but no one can expect to pass much urine when the drinking ration is small. The urine may appear dark in colour and thick, but this may be expected under the circumstances and need not cause alarm.

Swelling of the legs is a common occurrence after some time in a boat, and is almost universal for a few days after rescue, but the condition subsides without treatment and is in itself a matter of no importance.

Exposure.—The first signs of exposure are spasmodic shivering and chattering of the teeth which, if prolonged, will become continuous and uncontrollable. If the man has a normal constitution this state need not cause alarm, but he should be watched. If, however, he becomes very pale, drowsy, numb, and indifferent to his surroundings, immediate remedial action must be taken. In a lifeboat the best remedy is for two or more men to strip and to place the sufferer naked between their bodies and so warm him as quickly as possible.

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Frostbite.—In true frostbite the skin, and sometimes deeper tissue, becomes actually frozen, and it should not be confused with " immersion foot " which is described later.

Frostbite is almost unknown unless the temperature of the air is as low as —10°C. (14°F.), and is only common if the temperature is much lower, *i.e.*, from —25° to —30°C. (—13° to —22°F.). On land, frostbite occurs only when the ground is frozen hard or covered with dry snow or ice ; at sea it is very rare unless the sea water is freezing. Wind encourages and sunlight discourages frostbite.

The damage is caused by minute crystals of ice forming within the skin. Uncovered parts of the skin are affected ; the exposed fingers, ears and nose are, in that order, the most likely parts to be affected. Frostbite may also affect parts which come in contact with anything very cold ; the feet when in contact with ice or frozen ground, for example, or the fingers when touching cold metal. The severest form of frostbite is usually found in the feet.

Signs of Frostbite.—The skin becomes pale and yellowish-white, looks unusually opaque, and feels of wooden hardness ; this hardness is the only reliable and invariable sign of freezing. The patch of skin thus affected usually looks and feels clearly marked off from the remainder. The freezing usually occurs in skin that is already tingling or numb with cold ; it occurs quite suddenly, sometimes after a sudden stinging pain or pricking feeling, but the actual moment of freezing is very apt to pass unnoticed. The frozen patch gets larger if untreated, but its increase is not felt. Once frozen the skin remains quite unchanged until it thaws, but then it becomes inflamed, the degree of inflammation depending upon the extent and hardness of the freezing.

Reaction to Frostbite.—As soon as the affected part has thawed the skin first becomes bright red and hot. A short freeze is then followed by itching of the skin, and the formation of a weal which disappears within a few hours, but a longer freeze is followed by burning pain and blistering. A severe freeze causes mortification, and the mortified area comes away after blackening and leaves a hole or ulcer in the flesh. A very severe and extensive freeze will cause death, or mortification of the end of the limb affected.

Prevention of Frostbite.—Everyone in the boat should endeavour to keep as warm as possible, and in intense cold plenty of windproof clothing, thick gloves and ear protectors should be worn. The feet and socks should be kept as dry as possible, and the feet should be kept moving to maintain circulation ; cramped positions should be avoided. Metal should not be touched with the bare hands or the lips. The hands and feet, if bare, and all exposed skin, such as the face should be kept greasy by rubbing in clean oil or vaseline. Beards and moustaches should be clipped short, otherwise the breath will form icicles in them. When passing urine the parts should be protected from the wind, and afterwards carefully dried.

Each man should occasionally watch his neighbour's face for the first signs of frostbite. The beginning of frostbite on the face can also be detected by wrinkling it up to find out if any parts of it are becoming stiff. A bare warm hand should be placed immediately on any affected part.

Small frozen areas can be thawed rapidly by covering them with a warm hand, and they should require no further treatment. Larger and more severe areas of frostbite in the limbs, such as a whole foot, should be thawed gently

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by placing the affected limb inside a companion's clothes. Frostbitten skin should not be rubbed with snow, or with anything else, and it should not be massaged.

Immersion Foot.—When the feet or legs are immersed for many hours in cold water or mud the tissues are very gradually damaged, the colder the water and the longer the immersion the greater being the damage. In the North Atlantic the sea is usually cold enough, even in summer, to cause such injury when northward of Latitude 50°N.

Signs of Immersion Foot.—Immersion in water cold enough to cause injury is distinctly painful, but this pain is not usually severe and soon lessens. Within half an hour the immersed part is red and numb, and it becomes difficult to move the toes ; this numbness and weakness then get worse, and within three hours the limb is a little swollen, the swelling slowly increasing, especially if the limb is hanging down. All these early signs quickly disappear when the limb is no longer immersed and can be warmed, unless the immersion has lasted for several days, in which case signs of damage will be more marked and last longer, and blisters or dark patches may appear and the skin become broken.

Prevention of Immersion Foot.—This injury being mainly caused by cold, and the chief source of cold in boats being bilge-water, the bottom of the boat should be kept as dry as possible. Even if seaboots are worn, the feet should be kept clear of the bilges as the water will penetrate through them. If boots and socks become wet they should be taken off at once and dried ; the socks should be wrung out and put on again quickly if no dry ones are available, and the feet and toes should be moved frequently.

Unless the weather is fairly warm, the feet should not be exposed for rubbing as exposure to the air will cool the feet more than the rubbing will warm them. The feet should only be rubbed very gently, because rubbing the skin when it is swollen, numb, or tender will do more harm than good. Greasing the feet is not of much value. It is most important to keep the upper parts of the body warm, and this also helps to keep the limbs warm. In a cold wind it is better to keep damp or wet clothes on, and wear an oilskin or mackintosh over them, than to strip and wring them out. Wearing tight garters or suspenders, tight boots, or any other tight clothing on the legs or round the wrists should be avoided because it impedes circulation.

Notes for Castaways

The following notes, which are based on actual experience, are intended only as a very general guide for survivors who may land on an island in the tropics and have to live there for some time before being picked up.

Indications of Land

The presence of land below the horizon may be indicated by any of the following signs :—

(i) Low cloud which does not alter its position in an otherwise clear sky ; such cloud is formed by the condensation of hot air rising from land.

(ii) Numerous birds flying in a fixed direction in the evenings ; they will almost certainly be flying towards land. The presence of an occasional bird at sea is of course no indication that land is near.

(iii) A patch of pale green haze in the sky, which will probably be the reflection of the lagoon of an atoll.

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Landing

Most tropical islands are either surrounded by a coral barrier reef enclosing coastal lagoons, or they consist of a ring of coral islets standing on a reef and enclosing a central lagoon. In both, seas or a swell will be breaking on the reef and forming a dangerous surf; the reef however, is rarely continuous, and a smooth break in the line of surf will probably indicate a passage through the reef into the sheltered lagoon. Landing through the surf is a hazardous operation unless executed by an experienced and skilful crew, and even then is often impossible, and a boat should therefore always first cruise round the outskirts of the reef to find a suitable passage through it. If the island is inhabited the natives will most probably put out in a canoe and pilot the boat inshore.

If there is a possibility of the boat being cast onto a coral reef everyone should put on his boots and cover his hands with strips of clothing or canvas, because coral has extremely sharp points which can cause serious injuries.

Natives

If the island is inhabited the natives will probably be friendly and willing to help. Friendly relations with them should be encouraged but should not be allowed to grow into familiarity. If possible a separate camp for the survivors should be set up near the village, preferably above and to windward of it, and close contact with the natives, such as eating or sleeping in their huts, should be forbidden. On no account should their women folk be molested or enticed in any way, or any sexual relationship be entered into.

All matters should be arranged with the chief or headman of the village, and the officer in charge should work in close co-operation with him.

The native food will be wholesome if cooked, but the water may well be contaminated and should be boiled or distilled before being drunk. Soft-skinned fruit and vegetables should not be eaten raw, and any hard-skinned fruit should always be peeled before being eaten.

Water

If the island is uninhabited one of the first tasks is to find fresh water. If no stream can be found but there is plenty of vegetation, water will probably be found not far below the surface of the ground. The best place to start digging is along the foreshore above the beach. If any water found there is too brackish to drink, holes should be dug further inland, preferably in hollows, until water fit to drink is discovered.

Water can also be found in the hollow stems of rank vegetation and of some trees; it may also be found trapped in the large leaves of various plants.

In an uninhabited island the water will probably be uncontaminated and fit to drink without first being boiled. If no containers are available for boiling or heating water, this can be done either by dropping heated stones into small pools of water in rocks, or filling a length of the trunk of a bamboo with water and holding it over a fire; the water will boil before the bamboo catches alight.

Coconut Trees

These trees grow on most tropical islands and can be put to many uses. The nut is covered with a green, fibrous husk, which turns brown as it ripens. The fibres of the husks and of the leaves can be made into rope or lines by twisting them together into yarns and strands and then laying up the strands into

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rope. Shelters or huts can be made by plaiting the leaves over a framework of bamboo, and with a little ingenuity the leaves can be made into clothing.

The kernel of the nut can be eaten, but it is rather indigestible and may cause diarrhœa. The oil which can be squeezed out of the kernel is a good antidote for sunburn ; it also burns well with a bright flame, and a lamp can be contrived out of half a nut filled with oil, in which a wick made from the fibres of the husk is floated.

It is inadvisable to sleep under coconut trees, because a falling nut can easily kill a man if it drops on his head.

Making a Camp

A camp should, if possible, be sited on rising ground and on the windward side of vegetation to minimise any nuisance from winged insects. It should not be under coconut trees, or near any rotting vegetation, as this usually harbours scorpions, centipedes and possibly snakes ; nor should it be near, or to leeward of, stagnant water or marshy ground where mosquitoes are likely to breed.

Everyone should sleep on some form of bed standing at least a foot clear of the ground, to avoid the dew at night and also any crawling insects. Beds can be made by stretching plaited coconut fibres, vines, or leaves between four posts driven into the ground.

Latrines should be sited at a considerable distance to leeward of the camp and its water supplies or storage ; this will lessen the risk of contamination of the water and mitigate any nuisance from flies. Where possible the latrines should discharge into the sea, but if this is impossible a deep trench should be dug and all excrement should be covered with earth immediately it is passed ; unless the greatest care is taken to cover it there will be a considerable risk of dysentery.

Cleanliness in and around the camp is essential. Food should always be covered, and any gash left over from meals should be buried.

If water is scarce every opportunity should be taken of catching and storing rainwater. The tarpaulins, boat cover, and any other waterproof sheets should be rigged as catchments to take advantage of the rainstorms which occur frequently in the tropics.

Salt is a necessity, particularly when a man is sweating much and drinking a lot of water. It can be obtained by evaporating sea water, either in shallow rock pools, or on a piece of canvas stretched in the sun and kept wet with sea water.

A distress signal, consisting of a coat, shirt, or other large piece of material, should be rigged from a conspicuous tree, and a bonfire and a smoke fire should be laid ready to light to attract the attention of any passing ship or aircraft ; smoke can be made by putting damp vegetation on a fire.

The letters S.O.S. together with the name of the ship should be marked out on a beach or clearing ; the letters should be as large as possible and of a sharply contrasting colour to the sand or ground.

Fishing and Poisonous Fish

Fish are plentiful and fairly easy to catch in tropical waters, and they provide a useful and palatable addition to the rations. Any fish which are caught should

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be cooked and eaten as soon as possible, because they go bad very quickly in the tropics.

If fish hooks, or metal with which to make them, are not available, useful hooks can be made from any hard wood, particularly bamboo. Bamboo is also good for making the barbed heads of fishing spears, which should be shaped like the spine of a fish. Live baits, such as small fish or shellfish, are the best, but if not procurable small strips of red and white bunting, wool, or other similar materials, make good baits when trolled through the water.

When fishing in tropical waters, however, great care must be taken to avoid the many venomous fish and shellfish, and wading in a lagoon should not be attempted unless the fisherman is wearing boots. He should also avoid groping in crevices or under submerged ledges of coral because voracious eels up to 10 feet in length and other fierce, predatory fish may lurk there.

Some fish are dangerous to handle because of the venomous spines on their backs or tails, and the flesh of others is poisonous when eaten. In general, avoid touching or handling any particularly spiny fish, alive or dead, or any brightly coloured, cone-shaped shellfish, and never eat any fish which inflates itself when scared or which is not covered with ordinary scales. Some of the more common dangerous fish and shellfish are illustrated in Figs. 80, 81 and 82, and are described below.

Stone Fish, Scorpion Fish, and Lion or Zebra Fish.—When fully grown these fish range in size from nine to eighteen inches. They are found on the bottom of shallow lagoons, often hidden in sand or in coral debris and stones. Their venom, which is injected by the spine as it punctures the skin, is as dangerous as that of a poisonous snake, *and the spines can inject the poison even when the fish is dead.*

Sting Ray.—This fish is found in varying sizes, in rivers and estuaries as well as the sea, and small rays are just as dangerous as the large ones. The tail carries barbed spines which can inject poison as well as inflict a severe wound. When trapped the fish lashes out with its tail with a force which can drive the spine through a seaboot.

Puffer Fish.—These grow to about a foot in length ; their bodies are covered with bristles, thorns and spikes instead of scales, and when frightened they inflate themselves into a shape like a bladder. Although safe to handle, their flesh is very poisonous when eaten.

Trigger Fish.—When fully grown these fish are also about a foot long. They are characterised by their bright colouring and the trigger-like horns above and behind the eyes. Though the horns are not poisonous they can inflict a wound when the fish is handled, and the flesh is poisonous to eat.

Sea-eggs and Sea Urchins.—These animals are contained in an egg-like shell from which grow hundreds of needle-sharp poisonous spines, two or three inches long. They usually lie hidden in the sandy foreshore of a lagoon near the water's edge. When trodden upon the spines pierce your foot and break off in it inflicting a painful and poisonous, but not fatal wound.

Shellfish.—Most shellfish, except those which are cone-shaped and usually brightly coloured, are edible ; they should, however, always be boiled, and then eaten, as soon as they are caught.

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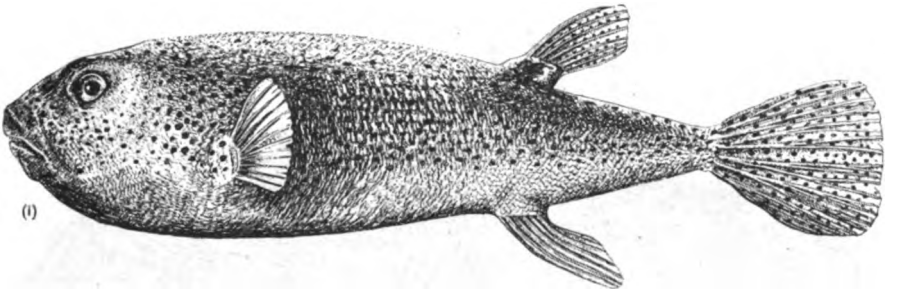

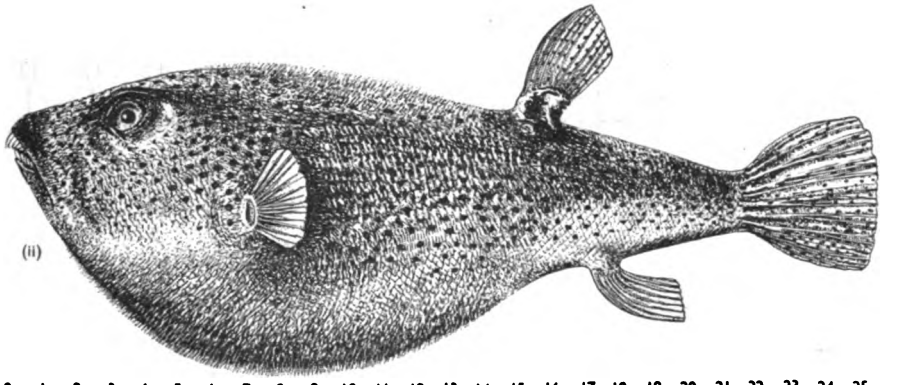

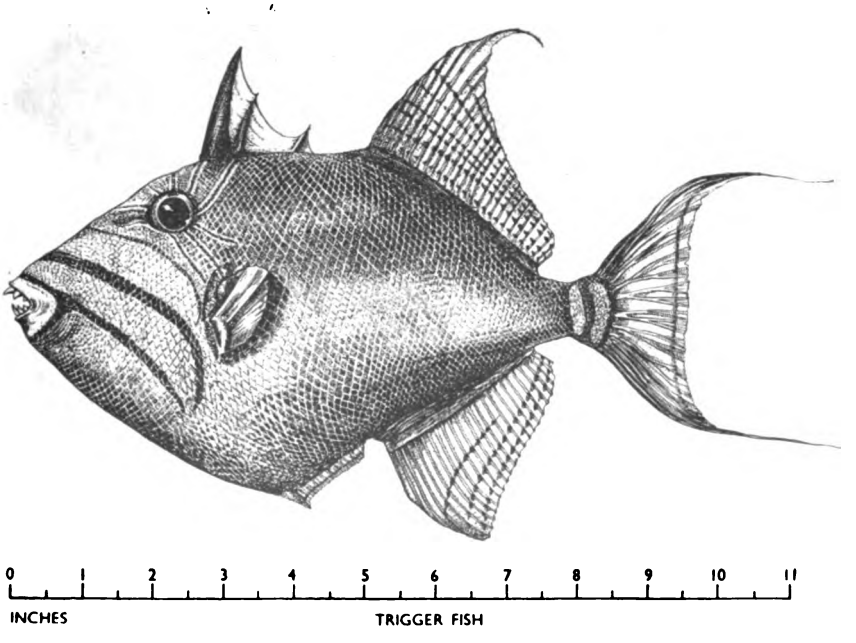

Fig. 80. Poisonous fish which must not be eaten

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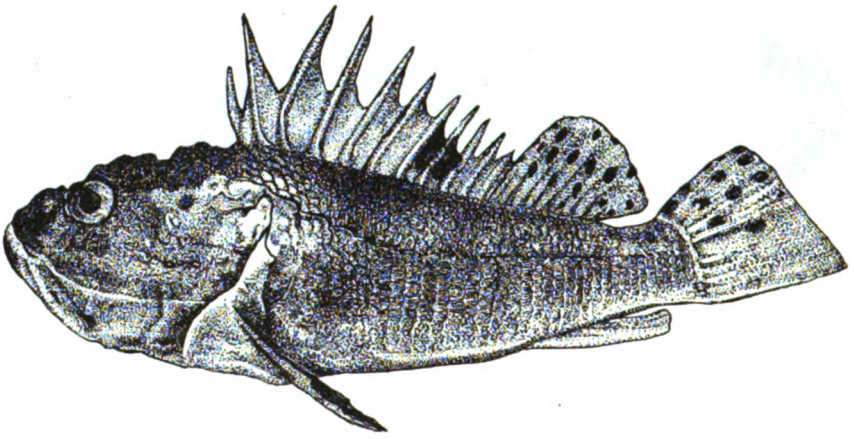
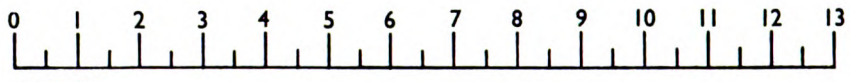
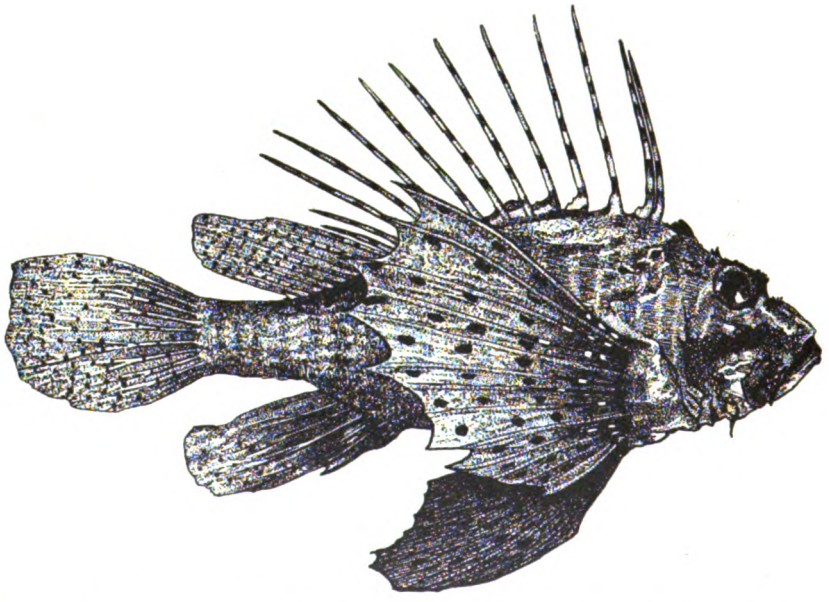
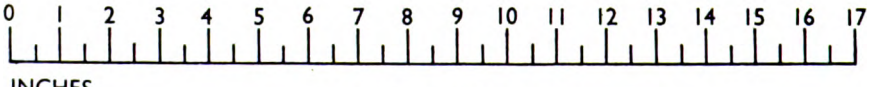




SCORPION FISH





LION OR ZEBRA FISH

Fig. 81. Venomous fish which must not be touched

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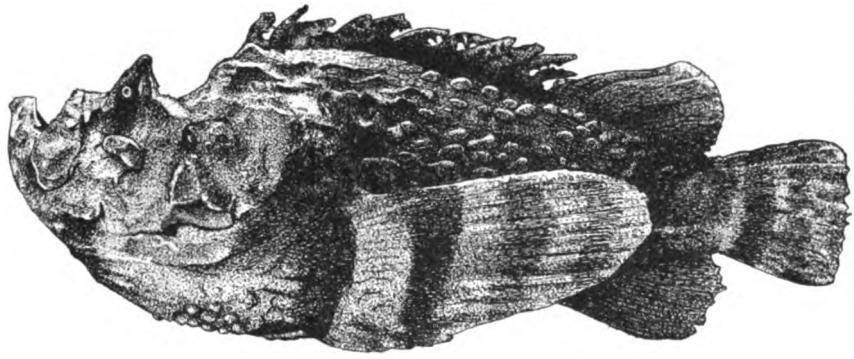
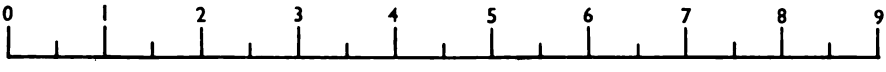
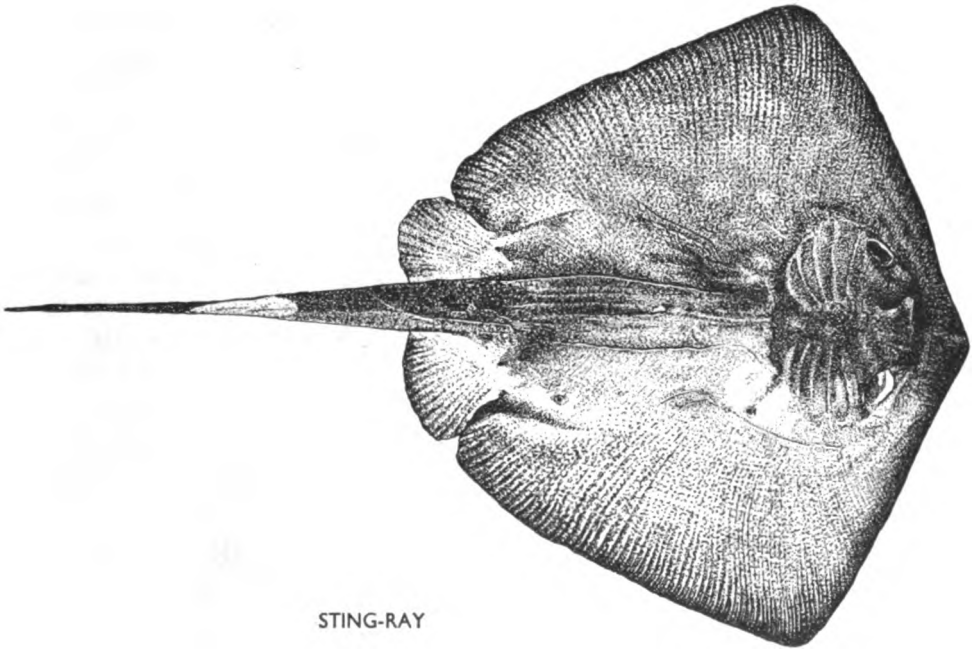




STONE FISH



STING-RAY

Fig. 81 (cont.). Venomous fish which must not be touched.

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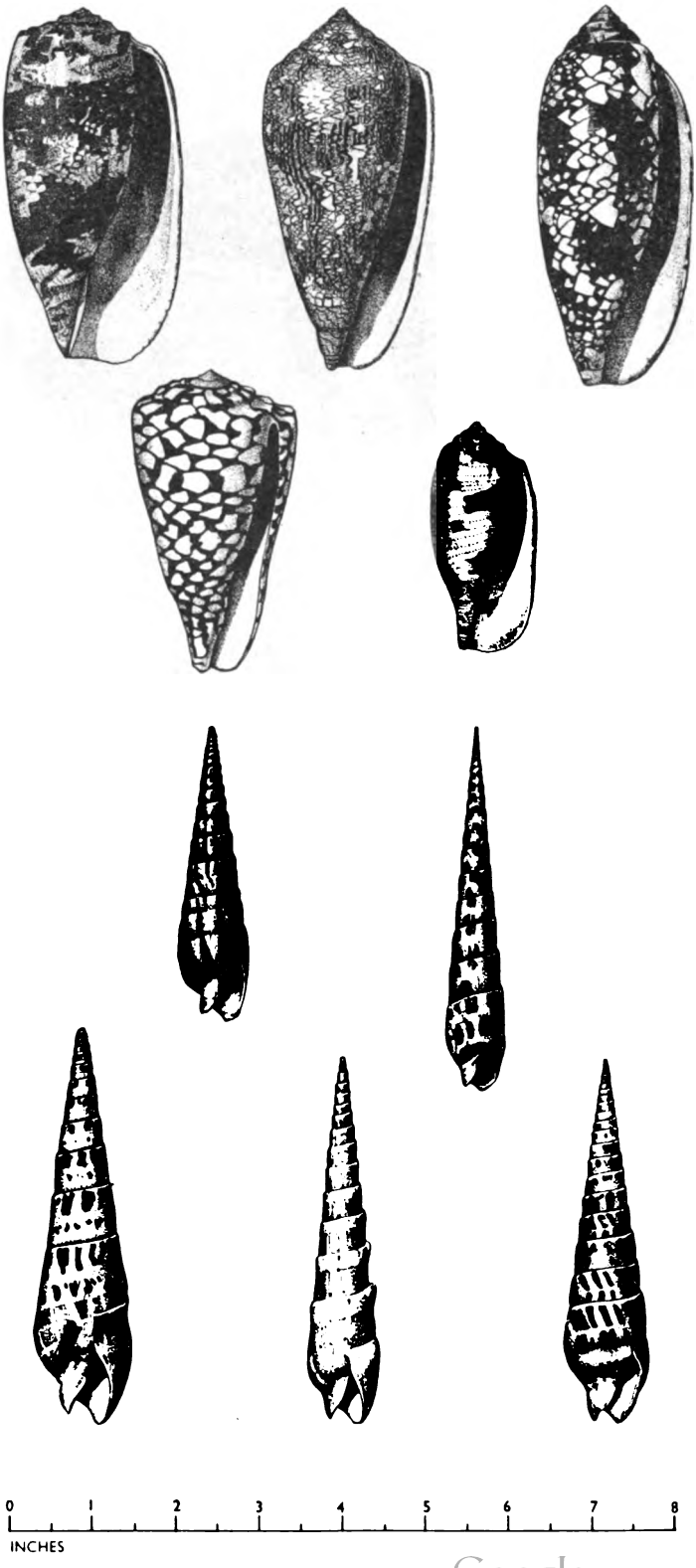

Fig. 82. Venomous shell-fish which must not be handled

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The more common kinds of poisonous shellfish are illustrated in Fig. 82: these can bite and their bite injects venom.

Snakes

Most snakes found in the tropics are venomous, so they should be avoided and no attempt be made to catch them. Contrary to popular belief snakes will seldom attack a man unless they are, or think they are, in danger of being trapped or trodden on. They like warmth and often lie basking in the sun, and then, owing to their protective colouring, they may be accidentally trodden upon. To gain warmth they will sometimes creep near the embers of a fire at night, or even coil themselves up beside a sleeping man. Whereas a snake can strike with great rapidity it cannot move particularly fast over the ground and can easily be outdistanced by a man.

Insects

Scorpions and large centipedes can inflict severe and painful, but not fatal, stings. They may be found under rotting wood and vegetation, and have a liking for footwear. Boots and shoes should therefore be shaken well before they are put on.

Mosquitoes in the tropics usually carry malaria. They rest by day and fly at night, and breed in stagnant pools and damp vegetation. If mosquitoes are about, the whole of the body should be kept covered as much as possible from sundown to sunrise.

Antidotes for Poisonous Bites and Stings

Snake Bite.—Make slashes, at least a quarter of an inch deep, in the wound and close to it on the side nearest the heart; then suck the slashes vigorously to extract the poison before it is carried by the blood stream to the heart (the poison is harmless if swallowed). The slashes should be made as soon as possible after being bitten. Any strong disinfectant should then be poured into the slashes.

Severe Stings by Poisonous Fish.—The treatment is similar to that for snake-bite. The broken spines of sea-eggs should be plucked out of the wound as soon as possible.

Minor Stings by Insects or Fish.—Rub the area with ammonia, or if none is available pass urine on it. Then keep it cool with cold-water compresses.

Fever.—A man who has suffered a poisonous bite or sting may suffer from fever for two or three days. He should be dosed with aspirin or quinine, kept warm, and rested.

RESCUE

The best method of rescuing survivors in boats or rafts is to hoist the boat or raft on board with the survivors in it; this may not be possible, however, because the boat or raft may be either too heavy, too cumbersome, or too fragile to hoist, or suitable slings and lifting gear may not be available, or the sea may be too rough. The next best method is to transfer the survivors into boats from the rescuing ship, either directly under the davits if the weather is calm enough or while lying-off the ship, and then to hoist the survivors on board in the ship's boats. If neither of these methods is practicable the survivors must be hoisted inboard individually or in small groups.

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In the average well-found ship all three methods are practicable, and rescue stations should be made out accordingly and the crew be exercised in each method. The station-bill should provide for rescuing as quickly as possible as many survivors as the ship can carry, hoisting inboard the sick and wounded, feeding, clothing and accommodating the survivors on board, and giving medical care and treatment to the sick, injured or wounded, and to those suffering from shock or exposure.

When rescuing survivors from the water it should be borne in mind that they will probably have little or no reserve of energy, and will either be unable to help themselves or will expend their remaining energy in trying to climb out of the water. Many men were lost in the Second World War while floating alongside a rescue ship because they were unable to climb up her nets or ladders, or even bend lifelines round themselves. It should also be borne in mind that when a ship is rolling there is, particularly on the lee side, a considerable surge close alongside which tends to draw a swimmer under the ship.

Rescue stations should therefore include a number of men with lifelines round them working over the side of the ship, or in the water close alongside, actively assisting survivors to safety. Whenever possible men swimming should be hoisted on board and not assisted up scramble-nets or ladders, because the latter method wastes their rescuers' time and energy ; the strength and energy of five active rescuers can be taxed to the utmost in assisting an oil-covered survivor to climb up a scramble-net to the deck of a destroyer.

Methods of Rescue and Types of Equipment

Hoisting survivors on board, either in their own boats or rafts or in the rescue-ship's boats, is a comparatively simple matter for the experienced seaman so these notes deal only with other methods and gear which proved successful in the Second World War for rescuing men floating in the water.

Stations.—Rescue stations should be amidships, well clear of the propellers and where the freeboard is lowest, and each station should be abreast a davit, derrick or crane which can be used for hoisting men inboard. At each station there should be a party of men detailed for working over the ship's side tending the lifelines of those working over the side, and providing lifelines for survivors and hoisting them on board ; provision should be made for relieving the men working over the side at frequent intervals. Stations should also be allocated for giving uninjured survivors dry clothing, warmth, hot drinks, food and rest, and first-aid stations should be arranged where the injured can be given medical attention.

Each rescue station should be provided with some or all of the following gear :—

(i) stout lifelines attached to canvas belts to be worn by men working over the side (each lifeline must be tended by two men inboard) ;

(ii) two stout lifelines rove as whips through blocks at the head of each davit ; the end of each lifeline should be fitted with a spring-hook so that it can be passed round a survivor and hooked to its own part, or hooked to the becket on his life-jacket ;

(iii) " hauling-in " lines, each having a large soft eye at the end and fitted with white painted corks, so that it can be flung to a survivor, will float, and can be seem at night ;

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(iv) some form of stretcher with slings which can be submerged sufficiently for an injured survivor to be floated over it and then hoisted on board ;

(v) a cargo net, or a rigid basket-type net, which can be lowered beneath the surface and then used to hoist two or more survivors at a time ;

(vi) ladders or scramble-nets rigged to provide support for the men working over the side ;

(vii) small Carley floats to be secured alongside and manned by the men working over the side ;

(viii) light grapnels on the end of stout heaving-lines for casting over helpless survivors floating out of reach of the rescuers.

Methods of rescuing men from the sea.—The following methods of rescuing large numbers of survivors floating in the water or clinging to wreckage were successfully used in the Second World War :—

(i) A cargo-net is slung over the side below a pair of davits, a whip being rove through a single block at each davit-head and the end bent to each of the lower corners of the net. Survivors then float over the lower end of the net and are hoisted on board parbuckle-fashion.

(ii) A hammock, laced canvas jacket, bosun's chair, or breeches buoy is used to hoist injured survivors on board.

(iii) Boat-booms are rigged with a jackstay, and an outhaul to haul out a scramble-net along the boom ; when the boom is swung out the lower side of the net should be well submerged. This is used to give large numbers of swimmers something to cling to, and keep them from drifting away from the rescue ship, until they can be dealt with.

(iv) A grass-line is bent to a buoy and fitted an intervals of a few feet with long beckets and cork floats. It is streamed astern when rescuing large numbers of swimmers, so that they can grasp the line and put the beckets round themselves. The inboard bight of the line is snatched into a block well forward, the swimmers then being hauled alongside.

(v) A 2-in. manila or a 4-in. grass, with a thimble eye at one end and fitted with beckets and floats as in (iv) above, is shackled to the head of an empty depth-charge case. The line is then led forward, outboard of all, to a position on the forecastle and belayed with plenty of slack ; the empty depth-charge case being then fired abeam with a reduced charge from the quarter thrower, and it should carry the end of the line some 25 yards or more abeam of the ship. This is used to provide support for one group of swimmers while another group are being rescued.

(vi) A line-throwing projector is used to pass a line to an isolated swimmer ; it must, of course, be powerful enough to cast a sufficiently robust line.

The following method was used successfully by aircraft carriers in the Second World War to rescue the crew of a ditched aircraft when it was impracticable to stop the ship to lower a boat. In one instance a crew was picked up from a dinghy in a wind of 14 knots and a sea of force 6 with the ship steaming at 8 knots. Each wireless mast abaft the island on the starboard, or navigational, side of the ship was rigged with a net which could be lowered to 2–3 ft. above the water when the mast was horizontal, the position of each net being so arranged that combined they covered a distance from the ship's side equal to the length of a mast.

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With the nets lowered the ship steamed towards the survivors on a course which would take the nets over them. When the survivors had grasped the nets the latter were hauled clear of the water and hoisted inboard by raising the masts.

The rig for a Fleet carrier comprised three cordage nets each 16 ft. wide by 6 ft. 3 in. deep, the jackstay being of 2½-in. manila, and the mesh of 2-in. manila and 15 in. square. Each net was fitted to a spreader consisting of a light wooden spar which was slung from the mast by 2½-in. manila recovery lines rove through single blocks on the mast. The positions of the blocks from the feet of the masts were :—

forward mast	...	inner block at 2 ft., outer block at 19 ft.
middle mast	...	inner block at 16 ft., outer block at 33 ft.
after mast	...	inner block at 30 ft., outer block at 47 ft.

Treatment of Survivors.

The care and treatment a survivor will require after rescue depends largely on the climate, the length of time he has been adrift, and any ill-effects caused by exposure. Survivors in tropical climates will probably only be suffering from lack of water and nourishment, and perhaps from sunburn, boils and sores. In very cold climates, however, they usually perish from the effects of exposure long before their bodily health is broken down, and when rescued after being adrift for any appreciable time they may be suffering from cold, frostbite or "immersion foot." In general the common remedies advocated in first-aid handbooks should be applied, and here some advice is given on how to treat those ailments peculiar to survivors from shipwreck.

Food and Drink.—A good drink, hot or cold, is one of the first things required. Any non-alcoholic drink will do, and no harm can result however much is drunk if at first it is taken only in small quantities at a time ; the worst that can occur from too much to drink is vomiting. At first only light and easily digestible food should be given, such as bread and milk, or a bowl of thick soup. Gradually a return to more solid food can be made, but too heavy or too large a meal may lead to indigestion. There is no cause for worry if constipation occurs for a few days.

Exposure.—Survivors rescued straight from the water are more likely to suffer from the effects of cold than those from lifeboats or rafts. When the temperature of the water is below 40° F. men are liable to succumb in from one to three hours, but many instances are known of survival after considerably longer periods in water at such temperatures. The chances of survival are much greater when the temperature of the sea is higher, and in tropical waters men have survived after being adrift in the sea or in floats for many days.

If a man feels particularly cold, he is shivering and his teeth are chattering, he should be warmed up by giving him hot drinks and putting him in a warm place, but if he is very pale, lethargic, numb, collapsed or unconscious through exposure to extreme cold (a probable state if his rectal temperature has fallen below 80·6°F.) he must be warmed immediately and rapidly.

If he is unconscious he should be undressed immediately and placed in a hot bath at a temperature of 110°F. for not longer than ten minutes, then dried with a towel and placed in warmed blankets. If his temperature does

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not then rise by at least 2°F. every ten minutes, the treatment should be repeated until his rectal temperature rises to about 93°F. Once his temperature has risen to the safe level of between 91° and 93°F. he is out of immediate danger, and rapid heating by immersion should be stopped, otherwise he may be scalded; instead he should be kept warm under hot blankets. If a bath is not available, hot water at a temperature of from 115° to 120°F., should be poured over his clothes, up his sleeves and trousers, and down his neck. Rapid heating can be very painful, and if the man is conscious a maximum bath temperature of 105° will probably be as much as he can stand.

Another method of rapid heating, which is almost as effective and probably more suitable for treating a number of survivors, is to put them in a hot, damp atmosphere similar to that of the steam room of a Turkish bath. Such an atmosphere might be produced by admitting steam to a bathroom, or failing this the men could be taken to a particularly hot place in a boiler-room or engine-room.

Survivors exposed to moderately cold temperatures for long periods should not be rapidly heated but be warmed slowly by hot-water bottles, electrically heated blankets or light-cradles.

Massaging and drugs or alcohol should be avoided.

Frostbite.—The conditions for, and symptoms of, frostbite have already been described on p. 286. The best way of thawing out the affected part is to put it in *cold* water while keeping the rest of the patient's body warmly wrapped up. On thawing, the skin will at once soften and quickly become pink or red. Any kind of massage, and rubbing with snow or any other substance is dangerous.

If pain is severe on thawing, cool the affected part again for a little while with cold water, ice or snow. After thawing, warming up must be very gradual; it is dangerous to apply hot water, or hot-water bottles, or to warm the affected part in front of a fire.

Clean and dry the affected part as gently as possible, dust it carefully with sulphonamide powder, then wrap it in clean material and see that it is kept absolutely resting. Blisters or other breaks in the skin should only be opened by a doctor, otherwise complications may set in.

After initial treatment the body should be kept warm and the damaged part clean, and the patient should be given a hot meal.

Immersion Foot.—The conditions for, and the symptoms of, immersion foot have already been described on p. 287, and its treatment must begin immediately after rescue.

As soon as the patient arrives on board all his clothes should be removed, and he should then be wrapped in warm blankets. Hot bottles may be placed between the blankets, near his body, but not near the affected limbs, which should always be kept cool. The limbs may be cooled by the use of fans, and even ice if necessary, but no ice should be allowed actually to touch the skin. While desirable that the temperature of the skin should be reduced to about 80°F. it is highly undesirable that it should be reduced much below 70°F.; the skin temperature should therefore be taken frequently by placing a bath thermometer against the skin under a light covering of cotton wool.

The limbs will swell again if allowed to warm up too quickly, and they should be handled very gently; heating or rubbing them in any way is harmful. The

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treatment should be continued until all swelling has gone and the patient is able to walk without pain, or until he comes under the care of a doctor.

All blisters, open sores, or darkened areas of skin, should be dusted with sulphonamide powder and covered with clean, dry cloths; the feet and legs should be kept quite dry, and no lotions, ointments, or antiseptics other than the powder should be applied.

Removal of oil fuel.—Oil fuel on the skin is uncomfortable but not dangerous. It should be removed with " turkey-red oil " when more urgent matters have been attended to.

A rag or a wad of cotton waste should be damped with the oil and gently rubbed over the parts affected, using as much fresh waste as necessary. Afterwards, the parts should be washed with soap and water.

Wounds and burnt areas should not be treated in this manner, but in the usual manner described in the first-aid manuals.

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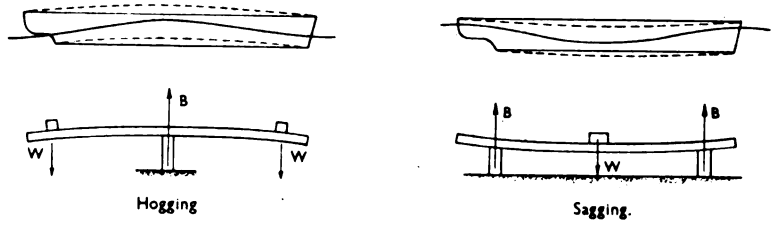
CHAPTER XIV

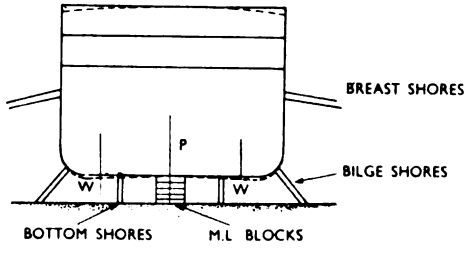
Warship Construction

THIS CHAPTER is devoted mainly to the principles upon which warships are designed and constructed to enable them to withstand damage by the sea and the effects of shell, bomb, and underwater explosions. Details of the numerous elements which combine to form the completed structure are to be found in *BR.569, The Practical Construction of Warships.*

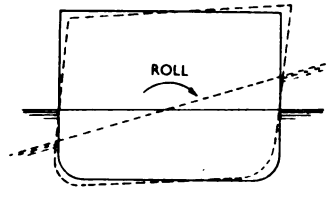
The problem of determining the best disposition of the main structural members to withstand the strains imposed on a ship in a seaway, is dealt with by assuming the ship to be statically balanced on a wave of length equal to that of the ship, and of height, from crest to trough, equal to one-twentieth the length. When balanced with the crest of the wave amidships the ends of the hull tend to drop, and the hull is said to be " hogging " ; with the trough amidships the hull tends to drop in the centre and is said to be " sagging " (see Fig. 83).



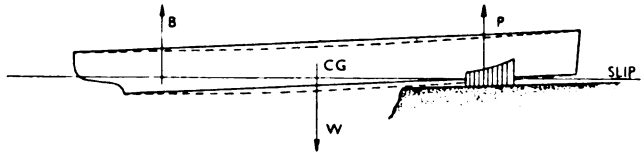
(i) Longitudinal bending in a seaway



(ii) Transverse bending in dock.



(iii) Racking strains when rolling.



(iv) Longitudinal bending during launching.

Fig. 83. Stresses experienced by ships

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The calculations involved are similar to those for a loaded beam, and show that the maximum tensile and compressive stresses occur about midway along the hull. At any section of the ship the stress is zero at the " neutral axis," which is a transverse axis through the centre of gravity of the material of the section (usually at about its mid-depth), and it gradually increases above and below this axis. On one side of this axis the stress is tensile and on the other compressive ; in the hogging condition the upper members of the structure are in tension and the lower members in compression, and in the sagging condition the reverse is the case. The same calculations show that the maximum shearing forces occur at about one quarter of the length from each end of the hull.

Transverse stresses are similar in character to the longitudinal stresses, but somewhat smaller in magnitude. They are usually greatest when the ship is docked (for which reason large ships are provided with the side docking keels), and when the ship is rolling. (See Fig. 83.)

If this orthodox investigation alone determined the constitution of the structure of a ship, one would expect to find the thickest members of the structure amidships at the top and bottom of the section to combat the greatest longitudinal stresses ; and similarly one would expect the more robust connections, together with the heaviest bracketing and main transverse bulkheads, to be at about one quarter of the length from amidships to combat the heavy shearing forces and transverse stresses which occur there. In merchant ships this is, in fact, usually the case, with departures from these principles occurring only where the hull is subjected to local stresses ; under the engines, boilers, and cargo holds, for example, and in the vicinity of the shaft brackets and tubes.

These principles of construction are equally true in warships, but their application is not easy to detect because so much of the general structure is designed to meet other special requirements. Examples of this are given below :—

Protective decks fulfil the dual function of providing structural strength and resisting penetration by shell or bomb.

Plating behind side armour or under deck armour is thicker than is required for hull strength alone because it has also to support the weight of the armour and assist the latter to take the shock caused by shell, bomb, or torpedo explosion ; the same applies to plating for the magazines and shell room bulkheads.

Non-magnetic protective plating on the compass platform serves the purpose of protection against aircraft fire or splinters and at the same time does not affect the accuracy of the magnetic compass.

The object of the massive barbette structures in the way of heavy guns, to withstand and distribute the forces of the recoil, is obvious, but at the same time such structures do fulfil their elementary part in the general strength of the ship to resist straining action caused by the forces of the sea.

From these few examples it is abundantly clear that no specific rules like those of Lloyds or the British Corporation societies can be laid down for the scantlings of any particular part of a warship's structure. Each case must be

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treated on its merits, and in conjunction with adjacent structures, to ensure that any part of the structure will possess the following properties :—

(i) strength to resist the natural forces arising in a seaway ;
(ii) continuity of strength with adjacent structures so that no sudden change of strength occurs ;
(iii) ability to withstand local stresses *e.g.* propeller thrust, engine vibration, concentrated loading in the way of heavy guns and machinery, etc. ;
(iv) adequate resistance against the effects of shell, bomb, or underwater explosion.

A corollary arising from (ii) above is that when there appears to be no reason for the presence of an unusually large structural element, such as a bracket or heavy pillar which perhaps prevents a tier of kit lockers from being conveniently placed, the reason for its presence will probably be found in (i), (iii) or (iv) above.

Whilst the calculations and general design work involved by (i) and (ii) are, as already stated, orthodox, those required by (iii) and (iv) entail special investigation, and (iv) also entails continuous experimental work. The development of a new or improved type of armour is an example of (iv) as it involves intricate calculation, metallurgical analysis, development of manufacture, and full-scale range-trials.

The design of submarines falls in a special category. Longitudinal strength to resist the forces of the sea when on the surface is more than adequately provided by the structure necessary to withstand the compressive forces of the sea when deeply submerged, or the pressure wave of an underwater explosion. The orthodox calculations referred to for surface ships are of no use for submarines and the calculations and research to determine the most efficient disposition of material in the pressure hull and transverse frames are not only intricate but require careful analysis. In surface ships, strength calculations are based entirely upon the elastic theory of the strength of materials. In submarines the investigations take into account both elastic and plastic failure of the material of the hull, and consequently the yield-point of the steel used is of greater importance than in surface ship design. There is one particular rule in modern submarine design which might well be quoted here, *viz.*, that for a given weight of hull any departure from circularity in the cross-section of the pressure hull must be accompanied by a reduction of the safe diving depth. This is a rule which should always be kept in mind when comparing types.

Electric welding instead of riveting was introduced on a considerable scale a few years before the Second World War (1939–1945), and during that war its development outstripped all other advances in the technique of ship construction. Its principal advantages are that it affords economy of weight, full scope for symmetrical disposition of the material, and a better continuity of strength by virtue of its complete, or almost complete, fixation of the joints.

The stage has now been reached when all submarines are completely welded, and much (in some cases all) of the structure of surface warships is welded. Large portions of the structure are now prefabricated in preference to welding a collection of small parts in place while on the slip.

This new technique, as in the older and well-tried riveting, has constantly to keep pace with new developments in the qualities of the steel used. Research is still necessary in the problems of welding cemented armour, bullet-proof

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plating, and certain special steels such as those of non-machinable and non-magnetic qualities, but reliable methods and electrodes are now available for all steels used in general structural work, such as M.S.D. (mild steel, ' D ' quality), D.W. (' D ' quality steel, weldable), S (submarine quality steel) and S.U. (submarine quality, unannealed).

Shipbuilding Materials

Steel

The main structure of the ship is composed of steel plates, girders and sections made of various qualities of steel of which the following are some examples.

D.W. quality steel is used in surface ships for all parts of the hull structure which contribute to longitudinal structural strength, and also for the main transverse bulkheads and supports in the way of guns. The associated connecting angles, stiffening, and bracketing are of the same quality. This steel supersedes the high tensile steel (D.H.T.) and the doubly high tensile steel (H.H.T.) previously used, and its special property is its adaptability to electric welding.

Mild steel is used elsewhere for the general structure, and for anchor cable which was previously made of wrought iron.

S quality steel was developed and is used for all welded submarine pressure-hull construction, including certain internal flats and pressure tanks, the end " domed " bulkheads, and other items. Elsewhere in the pressure-hull D.W. steel is used, and for the outer hull and casings mild steel is employed.

D.1.H.T. (heat treated) steel, a development from D quality steel, which has been superseded by D.W., is still used to some extent for protection, the splinter protection in the way of gun positions for example, and for the sides and decks of important positions in the bridge and superstructure.

Cast steel is used in three qualities. " A " quality is used for important structural castings such as hawsepipes, shaft brackets, stern tubes, stern castings, the rudder frame and the rudder head; " B " quality is used for fairleads, packing rings, winch beds, etc.; and " C " quality for unimportant castings which cannot be readily fabricated by electric welding.

For riveted connections the rivets selected must be of a quality to suit that of the parts to be joined. D.W.R. rivets are used for connecting D.W., D.1, or " S " quality steel, and mild steel rivets for mild steel work.

Non-ferrous Metals

Non-ferrous metals are not suitable for the main structure of the ship, but they are employed extensively for bearings, various fittings, and some minor structures.

Naval brass is used for plates and sections in the vicinity of the magnetic compass if non-magnetic steel is not specified for protective purposes. It is also used widely for small fittings.

Gunmetal is used for valves and other fittings subject to corrosion. It is mainly an alloy of copper and tin, the latter giving it immunity from corrosion.

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Phosphor bronze is particularly suitable for bearings and sleeves : for machinery bearings and journals, for example, and for the rudder, shaft brackets and tube bushes.

Manganese bronze is used for machinery parts and castings, and for tubes and piping required to withstand internal pressure. In submarines the upper conning tower casting is made of manganese bronze if it is within a specified distance of the magnetic compass.

Aluminium alloy enables considerable saving in weight where strength is not important. It is used for such fittings as handwheels, kit lockers and mess racks, and in the latest destroyers the plating and rivets of minor bulkheads are constructed of it.

Wood has been largely superseded as the principal material for furniture and office fittings by light sheeting of steel or aluminium alloy, on account of the danger from fire. It is, however, still used for covering weather decks in large ships.

Tests and Strengths

All metals used in warship construction are subjected to specified tests before acceptance. These usually include a tensile and a bend test, and, if applicable, a hot-forge test to determine their malleability and a usage test. As an example of the latter, large castings are hammered, and also dropped from a specified height or position, to prove their soundness.

Special precautions in the heat treatment of those parts of the structure which have to be smithed to shape are necessary, and such operations as flame-cutting may be prohibited on special steels, especially if they are subsequently to be welded.

The strengths of the shipbuilding materials described are given in the following table.

Material	*Breaking Stress tons per square inch*
D.W. Steel	33
Mild Steel	26
S Steel	30
D.1.H.T. Steel	37
Cast Steel " A "	30
Cast Steel " B " and " C "	26
Naval Brass	26
Gunmetal	14
Phosphor Bronze sleeves	15
Phosphor Bronze bearings	7½
Manganese Bronze ...	28
Aluminium Alloy ...	11

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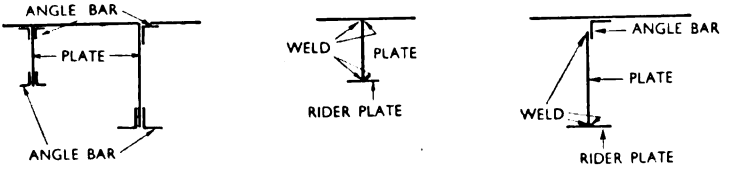
Methods of Connection

There are two methods of joining together the various members of the structure: riveting and the comparatively recent electric welding. Both enable the two fundamental requirements to be met, *viz.*, continuity of strength between the parts joined and rigidity. A third requirement, that of making the connection watertight, is more easily obtained by welding than by riveting. In addition, welding has the advantages that it enables a better and more symmetrical disposition of the material, it effects a considerable saving in weight because it requires no flanges, rivet heads or points, and it provides a complete, or nearly complete fixation of the joint, and so provides more rigidity. Strain

SECTION	TYPICAL SCANTLINGS	WHERE USED	
		RIVETED STRUCTURE	WELDED STRUCTURE
ANGLE BAR	2½" × 1½" × 3·20 LBS 3½" × 3" × 10·2 LBS. 4" × 4" × 12·75 LBS. 6" × 6" × 24·2 LBS.	CONNECTIONS GENERALLY STIFFENERS, BOUNDARIES, TO DECKS & BULKHEADS SIDE FRAMING	REPLACES [BAR FOR STIFFENERS TO BULKHEADS DECK GIRDERS & BEAMS SIDE FRAMING
ANGLE BULB	5" × 2½" × 8·49 LBS 9" × 3½" × 21·2 LBS 8" × 3" × 17·2 LBS	BEAMS & FRAMING FOR GOOD APPEARANCE IN OLDER SHIPS BECOMING OBSOLETE	NOT USED
FLAT BAR OR STRIP	5" × ½" × 4·25 LBS 12" × ½" × 10·0 LBS 8" × ⅜" × 10·2 LBS 8" × ½" × 13·6 LBS	EDGESTRIPS & BUTTSTRAPS	REPLACES L BAR FOR STIFFENERS TO BULKHEADS, RIDER PLATES OF GIRDERS & FRAMES
TEE BAR	3" × 3" × 7·2 LBS 5" × 2½" × 8·5 LBS. 5" × 4" × 14·5 LBS 6" × 6" × 24·2 LBS	BOILER BEARERS, BOAT'S CRUTCHES STIFFENERS TO STEEL MASTS & DERRICKS	REPLACES I BAR FOR STIFFENERS TO BULKHEADS, DECK GIRDERS & BEAMS SIDE FRAMING
CHANNEL BAR	4" × 2" × 7 LBS. 6" × 3" × 12·4 LBS. 8" × 3" × 16 LBS. 12" × 4" × 31·3 LBS.	SIDE FRAMING, BEAMS, LONGITUDINAL GIRDERS, STIFFENING TO MAIN BULKHEADS	REPLACED BY ANGLE BAR
I BAR	5" × 4" × 18 LBS. 8" × 4" × 18 LBS. 2" × 5" × 32 LBS	STIFFENING TO MAIN TRANSVERSE & LONGITUDINAL BULKHEADS RUNWAYS	REPLACED BY TEE BAR

(i) Unit sections



Riveted Welded

(ii) Built up sections

Fig. 84. Ship-building sections

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in a riveted joint takes place in two ways, by slip of the rivets and elastic flexure of the material. In a welded joint no slip can occur without fracture, and this point must be borne in mind when disposing the connections of a composite structure.

The principal sections used for connecting plating and stiffening bulkheads, decks, bottom plating, etc., together with remarks indicating how welding influences the use to which they are put and the saving in weight effected, are given in Fig. 84. Examples illustrating how welding facilitates the fabrication of deep girders are also given.

Plating is specified in terms of its weight per square foot. As steel weighs 490 lb. per cubic foot, a plate one foot square and one inch thick would weigh 40·8 lb., and so plating specified as 40, 20 or 10 lb. would measure respectively nearly one inch, half an inch, and a quarter of an inch thick. For plating of 5 lb. and below the term " sheet " is more generally used than plating. Non-ferrous materials are similarly specified.

Sections are specified by the lengths of their sides and their weight per foot run. Thus a 3-in. × 3½-in. × 10 lb. angle bar signifies one whose flanges are respectively 3 inches and 3½ inches wide, and of such thickness that a one foot length of the bar weighs 10 lb. . The approximate average thickness of the web and flanges is quickly obtained by taking three-tenths of the poundage per foot and dividing it by their combined length in inches.

Riveting

Two qualities of rivets are used in warships : mild steel rivets for mild steel work, and D.W.R. quality for connecting D.W., D.1., H.T., or S quality plating or sections. Punching of rivet holes is only permitted in unimportant mild steel work ; in all other work the holes are drilled. The actual operation of riveting is usually carried out with pneumatic riveters ; hand riveting is more efficient but takes longer ; hydraulic riveting is permitted for certain work.

The different types of rivet are illustrated in Fig. 85, each being used for different kinds of work as explained below :—

(1) *Countersunk-head and -point rivets* are necessary where absolute tightness is essential, *e.g.*, in the flanges of boundary bars to oiltight compartments and in the outer bottom plating below the waterline. This is effected by countersinking the rivet hole at both ends and using rivets of appropriate shape, the angle of countersinking being varied according to the thickness of the parts joined.

(2) *Pan-head Conical-neck and Countersunk-point rivets* are used for oiltight and watertight work other than the above, it being sufficient to use pan-headed rivets with the neck coned to the same angle of 15 degrees.

(3) *Pan-head Conical-neck rivets* are used for non-watertight work in important structures, countersinking of the rivet hole on one side only being necessary. A very slight countersinking is worked on the point side of the hole to ensure proper filling.

(4) *Pan-head Straight-neck rivets* are suitable if the plating in (3) is less than 10 lb.

(5) *Snap-head rivets* can be used in unimportant structures, where a good appearance is desired or cost can be reduced.

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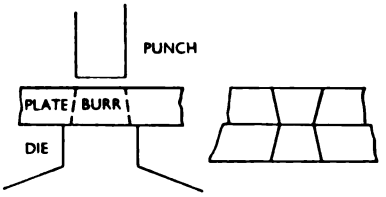
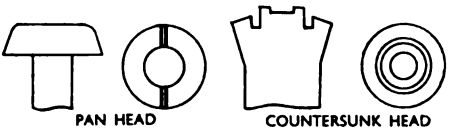
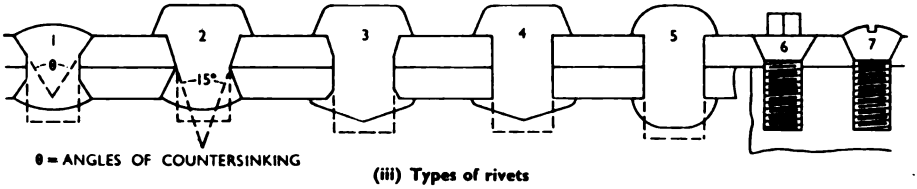


(i) Punched holes



(ii) Marking of D.W.R. rivets



(iii) Types of rivets

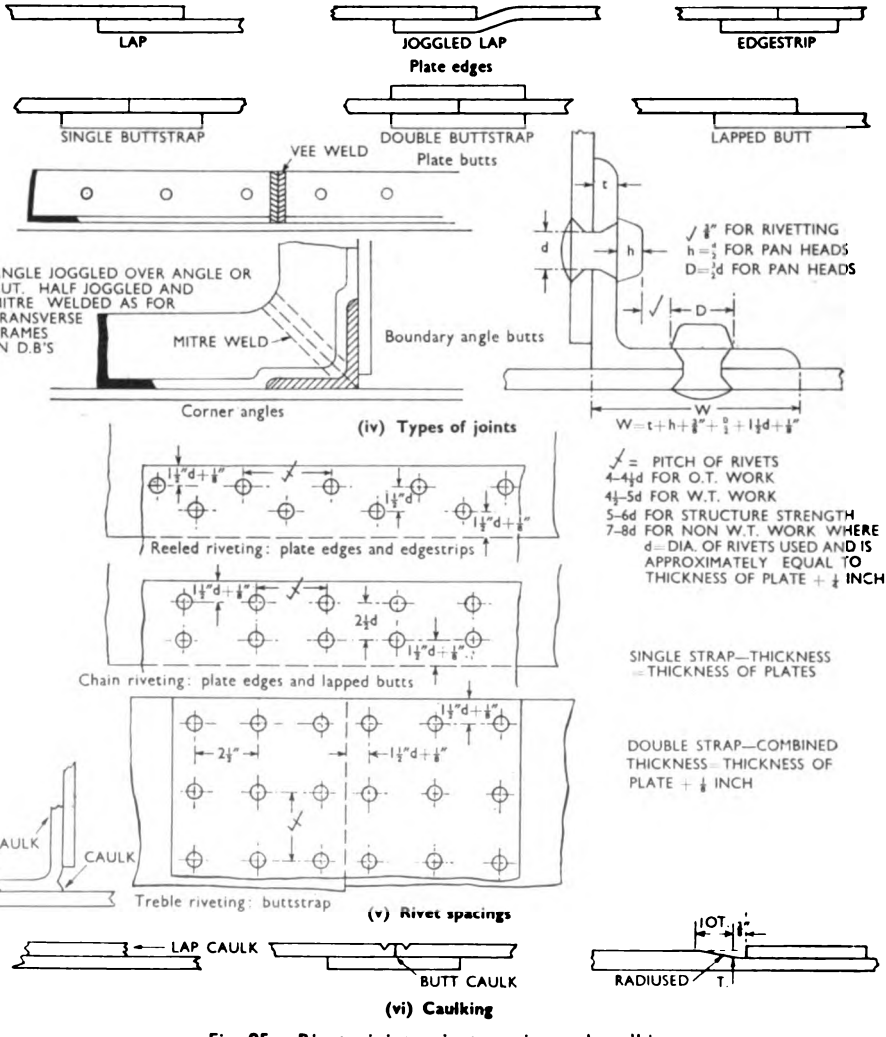


Fig. 85. Rivets, joints, rivet spacing and caulking

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(6) *Screw rivets* are required where access to the back of the joint is impossible, and also in very thick castings or armour plating.

(7) *Slot-headed Screw rivets* are used where plating has to be occasionally removed for survey of the structure, *e.g.*, for the wash plates around the propeller shaft recesses.

Fig. 85 also shows the different types of joint used, together with the rules for the pitch of the rivet holes in a row, the distance between adjacent rows of holes, and the distance between the nearest row and a plate edge. These rules must be strictly adhered to. The size of rivet used is related to the thickness of the plating joined, a general practical rule being that the diameter of the rivet should be equal to the thickness of the plating plus $\frac{1}{4}$ inch.

Watertightness and oiltightness can be ensured by riveting alone only if the faying (*i.e.*, joining) surfaces are carefully machined. For general hull structure, however, this would entail considerable extra cost and time, so the edges of the plates are caulked instead. This is done by a special caulking tool somewhat similar to a chisel and used in a similar fashion. A slight groove is hammered along one plate, about three-eighths of an inch above the join, thus expanding the lower edge of the metal on to the surface of the other plate and making a tight joint between the two.

Electric Welding

In addition to electric welding affording the advantages of economy in weight, symmetrical disposition of material, continuity of strength, and prefabrication, it makes repair work easier and obviates the special consideration necessary with riveting of the disposition of butts and other joints. A welded structure will withstand more flexure without leakage, so that watertightness results naturally if the welding is continuous and efficiently executed.

The disadvantages which attended the first introduction of welding have now been largely eliminated by experience. The use of radiography to search out defective joints which would otherwise remain undiscovered, and the employment of automatic machines by which the rate of feed of the electrode, current and speed of advance are controlled, have contributed greatly to improvement in general technique and to prefabrication of large portions of structure. Before these aids became available the fact that flaws in the completed weld could not be detected naturally resulted in a suspicion that this method of joining was not as efficient as riveting. A satisfactory technique has been developed to overcome the effects of the " distortion " which must occur in a structure due to contraction of the weld deposit, and danger from electric shock and injury to the eyes of the operator has been reduced to a negligible factor.

There remains but one important disadvantage, *viz.*, the fact that welding cannot be efficiently carried out in adverse weather such as rain, frost or snow. Although many large parts of the structure can be prefabricated under cover, a considerable amount of welding must still be carried out at the slip.

In British shipyards 60/100-volt D.C. generators are used, taking their supply from the A.C. mains. Several welders work off one generator, and shop circuits are now generally fed by A.C. mains in most shipyards.

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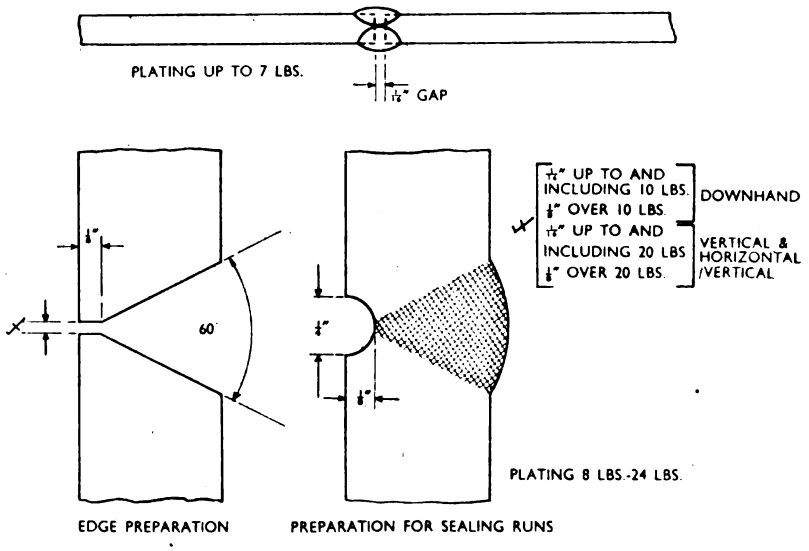
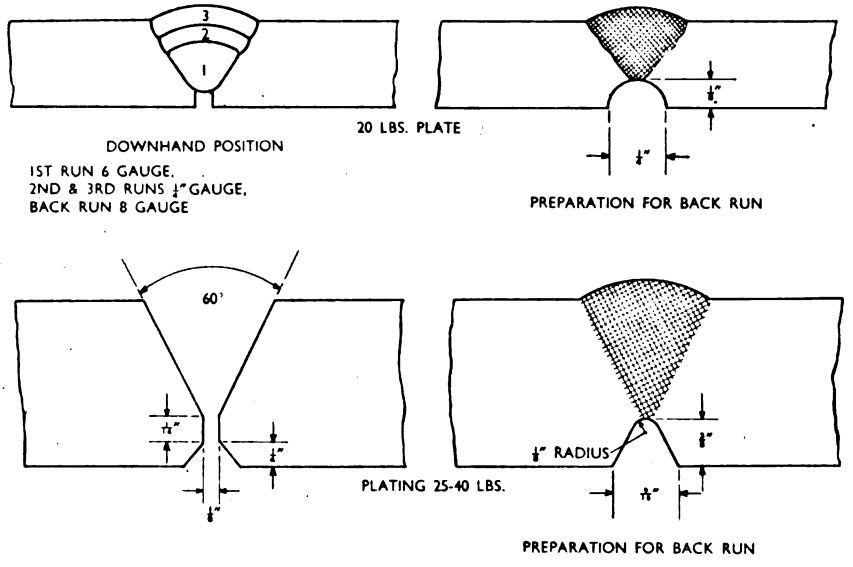


(i) Butt welds.



(ii) Typical arrangement of runs.

Fig. 86. Welding

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The important rules for efficient welding are given below :—

(i) The joint must be carefully prepared. The parts being joined must have properly machined faces when necessary, and cleanliness from dirt, rust, oil, paint, water, etc., is essential. Equally essential is the cutting out of the back of the weld (with a pneumatically operated round-nosed tool) down to bright, sound metal before depositing the back runs.

(ii) The correct current for the type of electrode provided must be used. If the current is low the deposit piles up and the resulting weld is lumpy and under length per electrode. Too high a current causes spluttering, undercutting and wastage.

(iii) The correct type of electrode must be used. All welding in warships is done with coated electrodes, the objects of the coating being to facilitate striking the arc and to prevent oxidisation of the molten metal by maintaining a protective layer of slag. *Complete removal of this slag before applying the next run is essential*, otherwise the parent metal cannot be penetrated by the deposit.

In Figs. 86 and 87, are illustrated the principal types of welded joint used for connecting the various parts of the structure of warships and some typical arrangements of runs, the dimensions indicated being those quoted in Admiralty specifications. With a few exceptions, a gauge 6 electrode is always used for the first run to obtain penetration at the root, and usually the same or larger gauge electrodes are used for the other runs. The type and gauge of electrode, and the current, to be used for any particular joint can be obtained by reference to authentic tables or to the welding specification.

The three principal types of joint are described below :—

(i) *Butt Joints.*—From the point of view of strength alone these are preferable to others. No bending action occurs under direct tension, and if it is efficiently made the junction may be accepted as being equivalent in strength to the parent plate. Chamfering of the plate edges is essential, the best angle usually being 30° with the vertical, thus forming a " 60° Vee weld."

(ii) *Lap Fillet Joints.*—When subjected to tension these become distorted unless the material is symmetrically disposed about the axis of pull. The weak spots are at the toes of the two welds, and any semblance of a notch here, *e.g.* undercutting, will promote a crack and accelerate fracture.

(iii) *Tee Fillet Joints.*—Good fitting of the edge of the abutting member to the passing member is essential for efficiency. It is not always practicable to obtain close fitting, and the alternatives illustrated in Fig. 87(ii), can then be adopted. With this type of joint the choice of size of the fillet is important and it depends upon the relative thickness of the parts joined and the quality of the steel of which each part is formed.

Intermittent welding, *i.e.*, short runs with gaps between them, is used where considerations of strength permit and watertightness is not required.

When deciding the type of joint, consideration must be given to the attitude of the weld relative to the operator, *e.g.*, whether it is " downhand," " vertical," " horizontal-vertical," or " overhead." These attitudes are described below.

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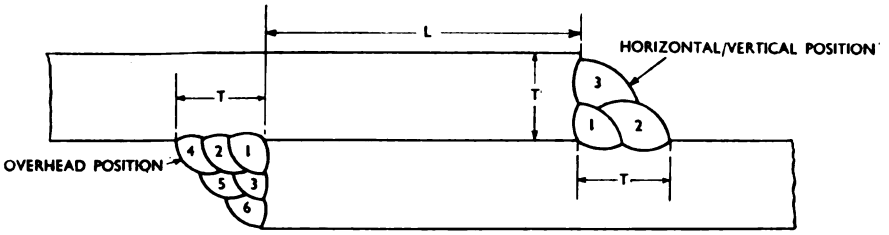
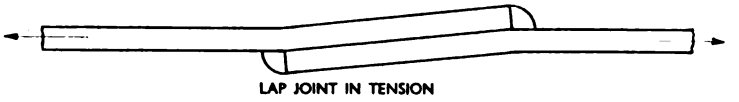


ARRANGEMENT OF RUNS SHOWN IS FOR 20 LBS. PLATING

L=3T FOR PLATING UNDER 10 LBS.
L=4T FOR PLATING OVER 10 LBS.
L IS NOT LESS THAN 1" FOR LAP ON ANGLE

T LEG LENGTH EQUAL TO THICKNESS OF PLATE



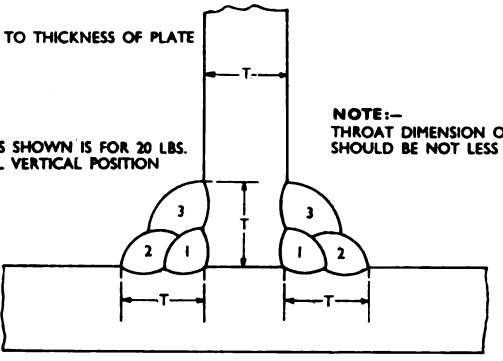
LAP JOINT IN TENSION

(i) Lap joints

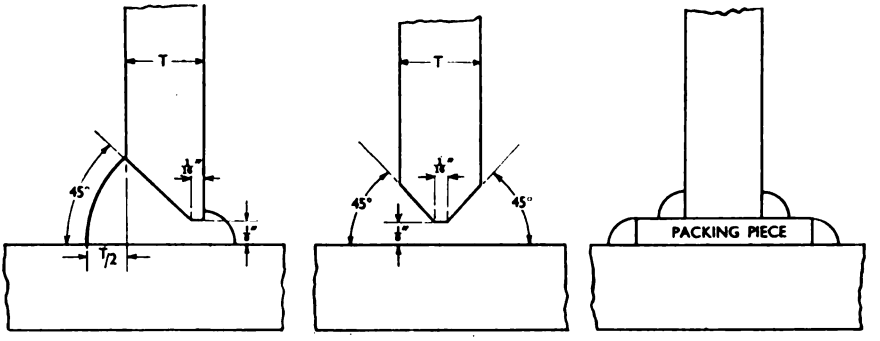
T LEG LENGTH EQUAL TO THICKNESS OF PLATE

ARRANGEMENTS OF RUNS SHOWN IS FOR 20 LBS. PLATING IN HORIZONTAL VERTICAL POSITION

NOTE:–
THROAT DIMENSION OF FILLET WELD SHOULD BE NOT LESS THAN 0.7 LEG LENGTH

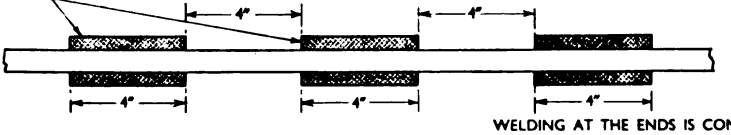


ALTERNATIVE ARRANGEMENTS IF ABUTTING MEMBERS DO NOT FIT CLOSELY



(ii) Tee joints

FULL SIZE FILLETS



WELDING AT THE ENDS IS CONTINUOUS FOR 12" OR FOR THE FULL DEPTH OF THE BRACKET IF FITTED

(iii) Intermittent welding

Fig. 87. Welded joints

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Downhand—the job is horizontal and the welding is applied from above in any direction. It is the best method because the flow and run of the deposit can be easily controlled.

Vertical—the job is vertical and the welding is applied up and down. It is not so good as downhand because the deposit tends to flow by gravity down the run.

Horizontal-vertical—the job is vertical and the welding is applied across it. It is not so good as either of the foregoing because the deposit tends to flow by gravity over the lower edge of the join.

Overhead—the job is horizontal and the welding is applied horizontally from below, in any direction. This is the least effective method because the flow and run of the deposit are very difficult to control.

If the structure is to be prefabricated, most of the welding can be executed downhand and so obtain the maximum reliability. Most types of electrode are suitable for all attitudes; some are made specifically for downhand welding. Broadly speaking, the principle to aim at is avoidance of overhead or vertical welding as much as possible, in both the shop and the ship.

Functions of the Principal Strength Members

The primary requirement of every member of a ship's structure is to ensure that the completed ship will withstand the forces of the sea and provide an adequate margin of safety and seaworthiness under all conditions of weather. In warships the margin of safety also covers certain hypothetical "damage" conditions, according to the class of ship and the destructive power of the

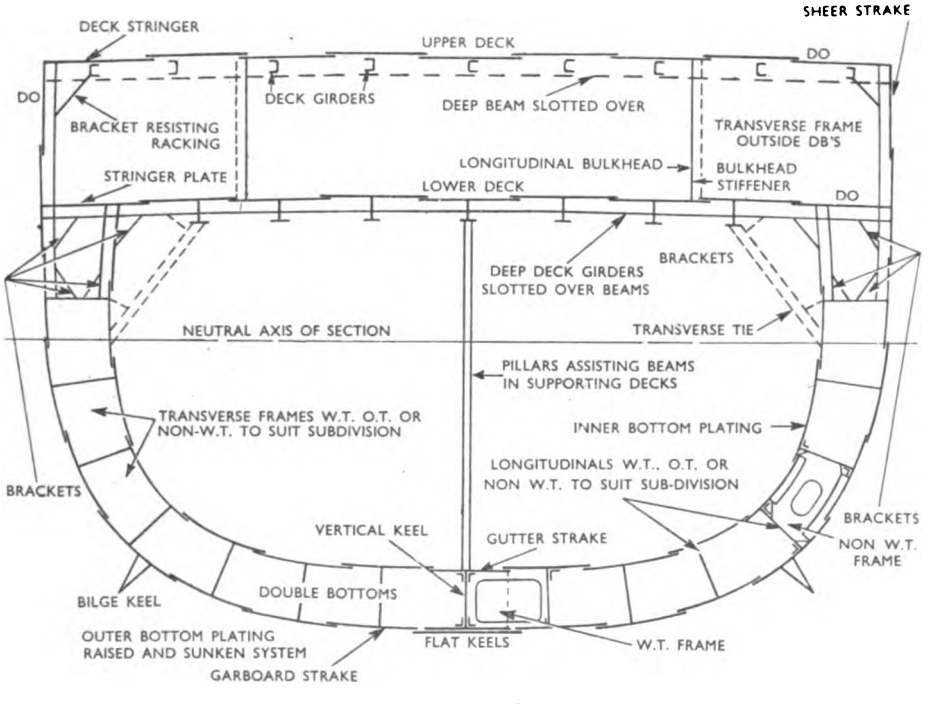

Fig. 88. Strength members of a ship's structure

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weapons likely to be carried by enemy ships of the same type. Each member has a particular function, but it is designed also to assist in distributing the stresses imposed on the ship so that the load is effectively shared by all members.

Framing

Before the introduction of electric welding the framework which stiffens the hull was built on a combination of the longitudinal and transverse systems. In the longitudinal system all the main girders running fore and aft are worked continuously and the transverse members are intercostal to them; in the transverse system this feature is reversed. Warships of riveted construction are built on the longitudinal system over the amidships length, to effect the greatest resistance to the heavy bending moments in a seaway, but at the ends they are built on the transverse system. To derive the maximum effect in stiffening the hull the two systems require to be very efficiently interwoven and connected together to form a compound girder. Close attention to the method of connecting intercostal girders to continuous girders, the slotting of decks, bulkheads or girders where other frames or girders pass through them, and the riveting at such positions, is essential.

Electric welding, by virtue of its complete fixation of joints, affords a complete combination of the two systems and a better distribution of the stresses at the junctions of the various members, and so gives the designer more scope for disposing the material in an economical and efficient manner.

The spacing and strength of the longitudinals and frames is a matter for careful consideration. Theoretically, the same strength could be obtained by a large number of light frames closely spaced as by a smaller number of heavier frames widely spaced, but actually the spacing is decided by two considerations. First, the frames must be so disposed and incorporated with the other structure of the ship that they afford the maximum assistance to the structure as a whole as regards longitudinal or transverse strength, and secondly, their disposition is affected by the size and type of ship and by the necessity for supporting her machinery, armament and other heavy equipment.

Broadly speaking, the smaller the vessel the more closely spaced are the frames and the smaller is the number of longitudinals. In cruisers and capital ships the spacing of transverse frames usually varies from 4 ft. to 6 ft., in destroyers from 1 ft. 9 ins. to 2 ft. 6 ins., and in frigates from 2 ft. 6 ins. to 2 ft. 9 ins. The closer spacing in small ships is necessary because thinner bottom plating is used to reduce the weight of the hull. In submarines the frames are more massive and spaced about 1 ft. 9 ins. apart with the particular object of resisting the severe strains imposed by the excessive water pressure when submerged.

In double-bottomed vessels the longitudinals and transverse frames extend the full depth between the inner and outer bottom, and the number of longitudinals each side of the vertical keel of vessels in which the inner bottom extends up the sides varies from seven to nine (see Fig. 89). Capital ships are provided with continuous protective longitudinal bulkheads abreast the machinery spaces, and the inner bottom extends outward only as far as these bulkheads so that the number of deep longitudinals is correspondingly less. Outside the limits of the double bottom, the longitudinals comprise single sections or built-up sections, their strength and disposition being designed to

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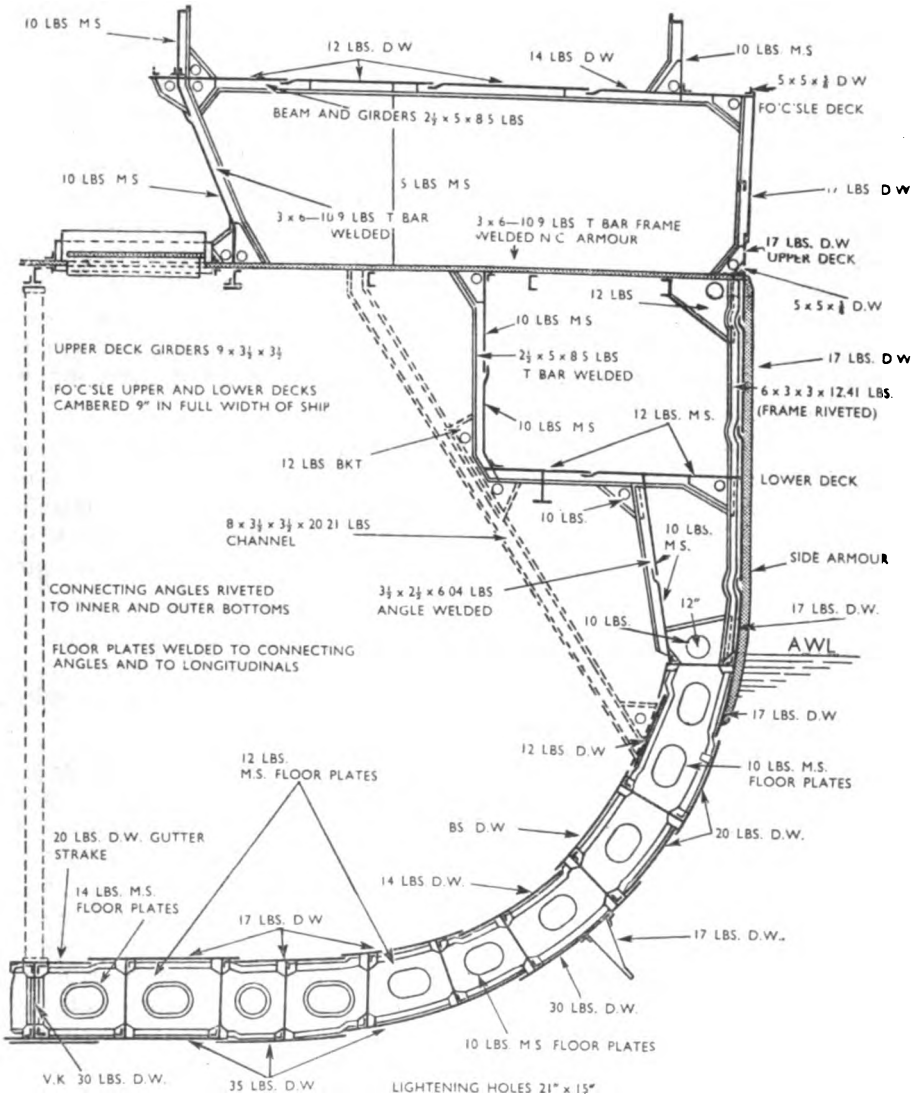
suit the particular ship and their position in the ship. This applies also to vessels not constructed with double bottoms.

The number and disposition of the longitudinals within the double bottoms depend upon the longitudinal strength required, which is of primary importance over this portion, and also upon the layout of the main machinery and boiler bearers. Where at all practicable the longitudinals are arranged to run directly under the machinery and boiler bearers, and where this


10 LBS M S
12 LBS. D W
14 LBS D W
10 LBS. M.S
5 x 5 x ⅜ D W
FO'C'SLE DECK
BEAM AND GIRDERS 2½ x 5 x 8 5 LBS
10 LBS M S
5 LBS M S
3 x 6—10 9 LBS T BAR WELDED
3 x 6—10 9 LBS T BAR FRAME WELDED N C ARMOUR
17 LBS. D W
17 LBS. D.W UPPER DECK
12 LBS
5 x 5 x ⅜ D.W
10 LBS M S
UPPER DECK GIRDERS 9 x 3½ x 3½
2½ x 5 x 8 5 LBS T BAR WELDED
17 LBS. D W
FO'C'SLE UPPER AND LOWER DECKS CAMBERED 9" IN FULL WIDTH OF SHIP
6 x 3 x 3 x 12.41 LBS. (FRAME RIVETED)
10 LBS M S
12 LBS. M S.
12 LBS BKT
LOWER DECK
10 LBS.
8 x 3½ x 3½ x 20 21 LBS CHANNEL
10 LBS. M.S.
SIDE ARMOUR
CONNECTING ANGLES RIVETED TO INNER AND OUTER BOTTOMS
3½ x 2½ x 6 04 LBS ANGLE WELDED
12"
17 LBS. D.W.
10 LBS.
FLOOR PLATES WELDED TO CONNECTING ANGLES AND TO LONGITUDINALS
AWL
17 LBS. D.W
12 LBS D.W
12 LBS. M.S. FLOOR PLATES
10 LBS. M.S. FLOOR PLATES
20 LBS. D.W. GUTTER STRAKE
BS D.W
20 LBS. D.W.
14 LBS. M.S. FLOOR PLATES
14 LBS D.W.
17 LBS. D W
17 LBS. D.W.
30 LBS. D.W.
10 LBS M S FLOOR PLATES
V.K 30 LBS. D.W.
35 LBS. D.W
LIGHTENING HOLES 21" x 15"
INNER FLAT KEEL 35 LBS D W
OUTER FLAT KEEL 35 LBS D W

LONGITUDINALS:—1st—20 lbs. D W 2nd, 3rd and 4th—17 lbs. D.W. 5th and 6th—14 lbs D W. 7th and 8th—12 lbs. D W. 9th—10 lbs. M.S.

Fig. 89. Midship section—cruiser

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is not possible arched frames are worked between main transverse frames under the bearers to transmit the load on the inner bottom to the transverse frames.

In capital ships fitted with side docking keels these are usually fitted under one of the longitudinals each side, each longitudinal being of similar construction to the vertical keel. The main machinery space bulkheads are placed over these longitudinals and serve to transmit the upward thrust to the main structure of the vessel when in dry dock.

Generally speaking, but with the exception of those over the side docking keels, the longitudinals are of lighter scantlings than the vertical keel.

The keel is the most important of the longitudinals. It is continuous throughout the length of the ship and comprises the middle strake of the inner bottom, the vertical keel, and the inner and outer flat keels (see Fig. 90). In some classes of ship two vertical keels are fitted to form a " box " keel. The inner flat keel is terminated a short distance before and abaft the double bottom. To ensure continuity of strength the vertical keel is not cut with lightening holes, even when non-watertight, except towards the ends of the ship. Inside the double bottoms it is usually watertight or oiltight throughout its length. Particular attention is paid to the connections of the keel where it joins the stem and stern castings or fabrications, and to the design of the keel throughout. Account is taken of its function in taking heavy loads during docking and after the ship is docked down.

It is not necessary to carry all the longitudinals right forward and aft beyond the limits of the double bottom owing to the decreasing girth of the ship and the reduced requirements of longitudinal strength, so only a certain number are carried on for approximately the full length of the vessel, and they are ultimately ended at bulkheads or run into flats, whichever method is more practicable (see Fig. 91).

From the extremities of the double bottom the depth of those longitudinals carried on is gradually decreased to avoid discontinuity of strength, and within a length of about five frame spaces a junction is effected with a side-stringer, which thereafter replaces the longitudinal.

Inside the double bottoms the transverse frames, as well as the longitudinals, are built to the full depth between the inner and outer bottom, and they are of watertight or oiltight construction, as required to form the sides of tanks (see Fig. 92) ; elsewhere they are of non-watertight construction and fitted with manholes for access. Outside the double bottom the frames are made of channel, tee, or angle bar, according to whether riveting or welding is used. Deep web frames, built up of several sections, are fitted at intervals where specially required for local support. In ships not provided with an inner bottom the transverse frames under the main machinery and boilers take the form of deep girders, tapered in depth towards the sides where they form the side frames.

Whereas the longitudinals outside the double bottoms are gradually reduced in depth and scantlings toward the ends, this is not done with transverse frames, the strength of which depends largely upon their position, *e.g.*, in the way of barbettes, behind side armour, and where the shaft brackets and stern tubes are fitted.

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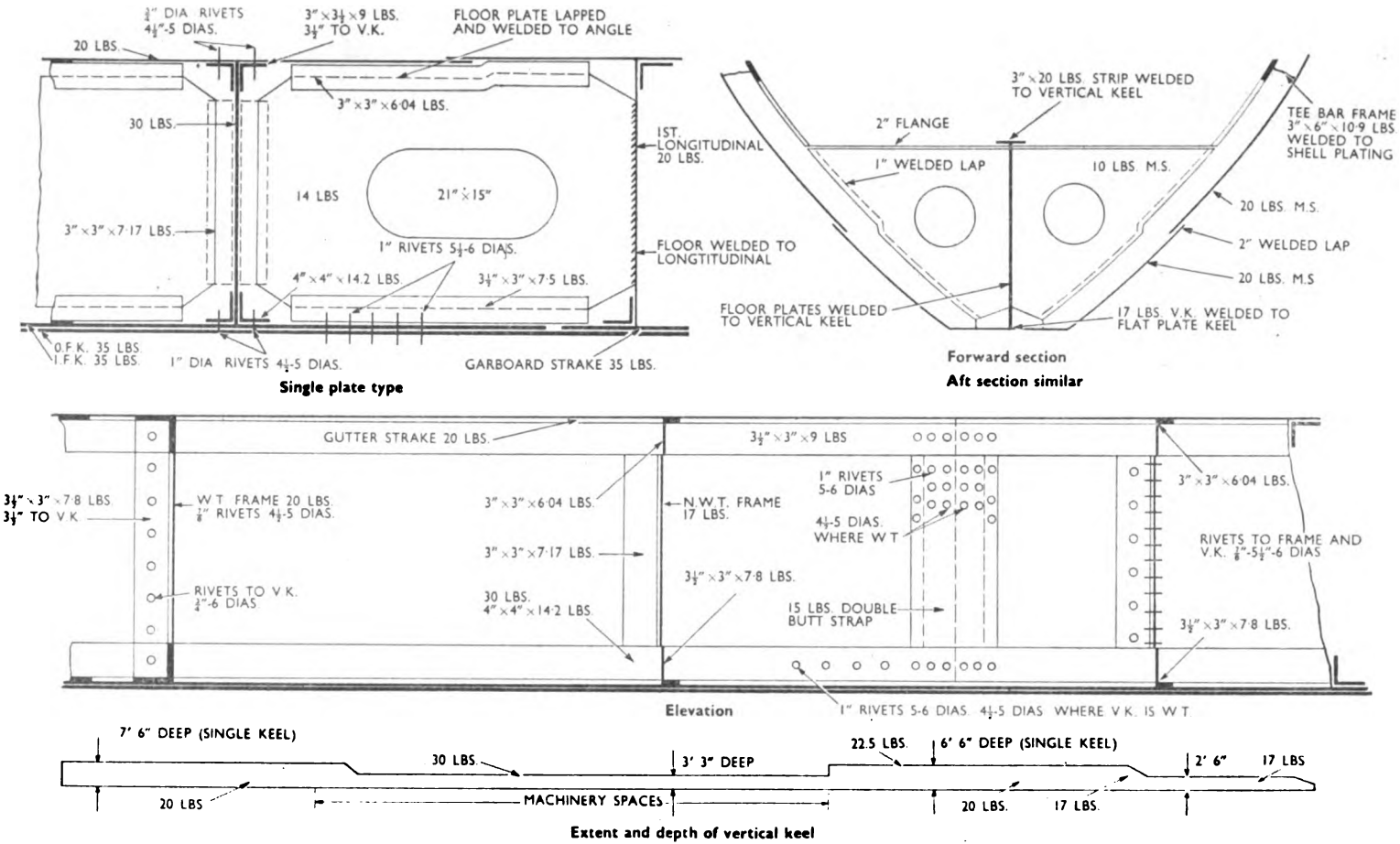

Fig. 90. Vertical keel

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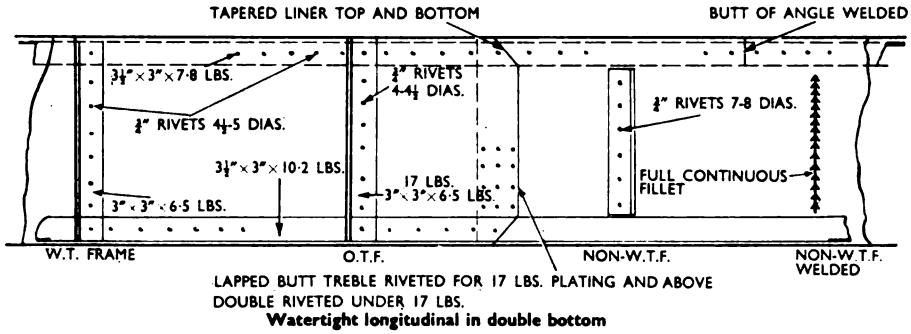
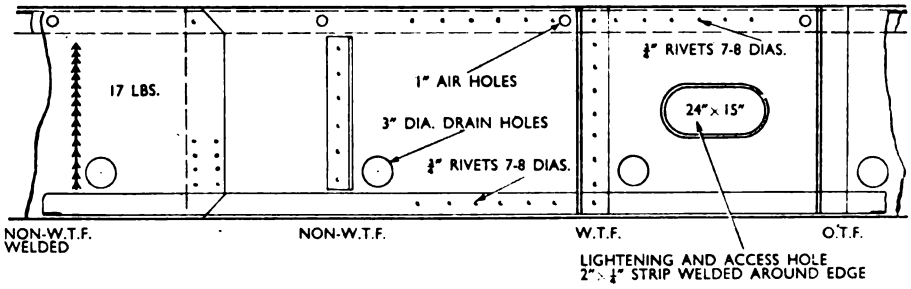
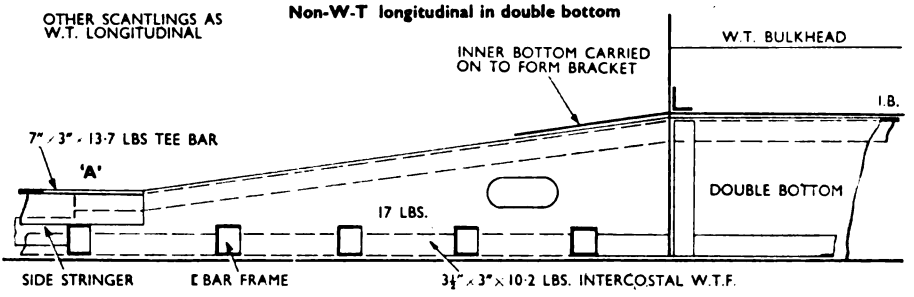

TAPERED LINER TOP AND BOTTOM
BUTT OF ANGLE WELDED
3½" × 3" × 7·8 LBS.
⅞" RIVETS 4-4½ DIAS.
⅞" RIVETS 4½-5 DIAS.
⅞" RIVETS 7-8 DIAS.
3½" × 3" × 10·2 LBS.
17 LBS.
3" × 3" × 6·5 LBS.
FULL CONTINUOUS FILLET
W.T. FRAME
O.T.F.
NON-W.T.F.
NON-W.T.F. WELDED
LAPPED BUTT TREBLE RIVETED FOR 17 LBS. PLATING AND ABOVE
DOUBLE RIVETED UNDER 17 LBS.

Watertight longitudinal in double bottom

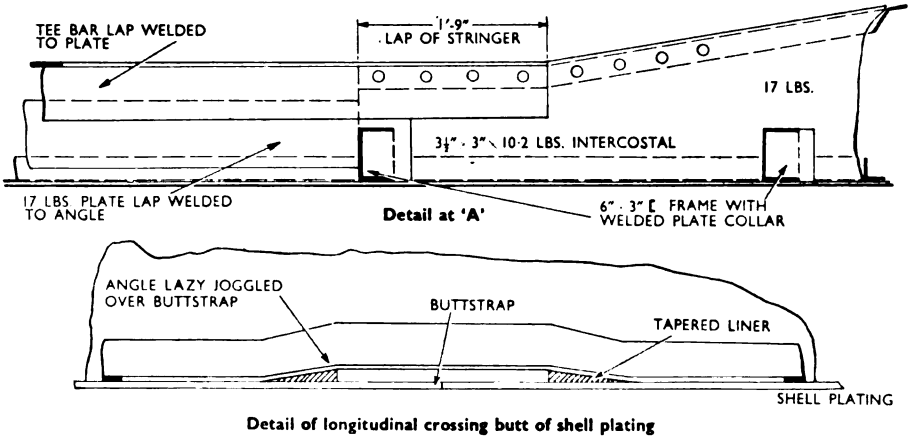
O.T. longitudinal similar, riveting in butts and top and bottom angle 4-4½ dia.



Non-W-T longitudinal in double bottom



Tapering of longitudinals outside double bottom


TEE BAR LAP WELDED TO PLATE
1'-9" LAP OF STRINGER
17 LBS.
3½" × 3" × 10·2 LBS. INTERCOSTAL
17 LBS. PLATE LAP WELDED TO ANGLE
Detail at 'A'
6" × 3" E FRAME WITH WELDED PLATE COLLAR
ANGLE LAZY JOGGLED OVER BUTTSTRAP
BUTTSTRAP
TAPERED LINER
SHELL PLATING

Detail of longitudinal crossing butt of shell plating

Fig. 91. Longitudinals

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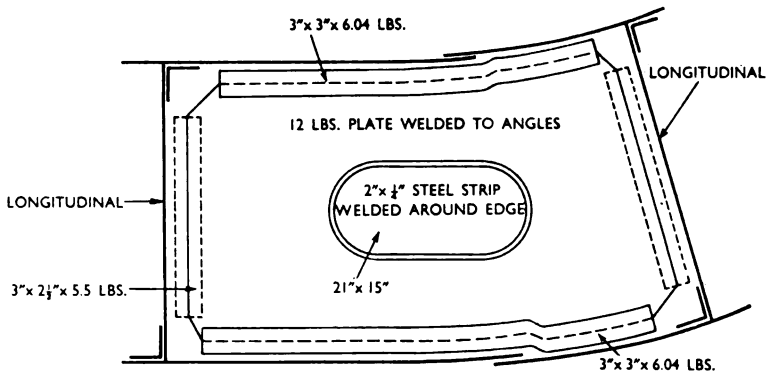
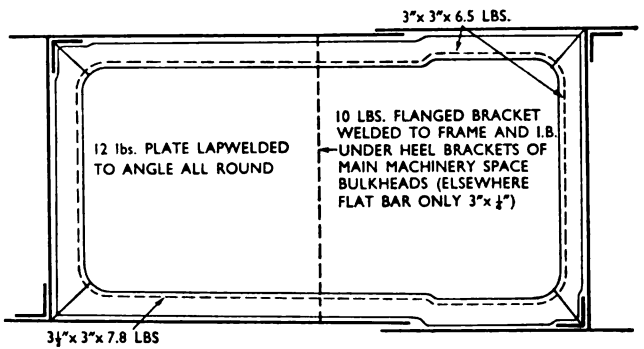
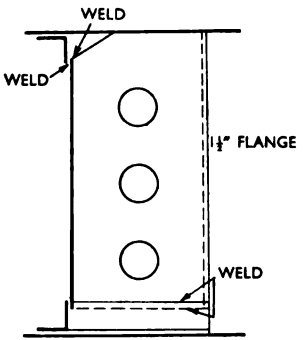

3"x 3"x 6.04 LBS.
LONGITUDINAL
12 LBS. PLATE WELDED TO ANGLES
2"x ¼" STEEL STRIP WELDED AROUND EDGE
LONGITUDINAL
21"x 15"
3"x 2½"x 5.5 LBS.
3"x 3"x 6.04 LBS.
ALTERNATIVELY—CONNECTING ANGLES TO LONGITUDINALS OMITTED AND PLATE WELDED DIRECT TO LONGITUDINAL

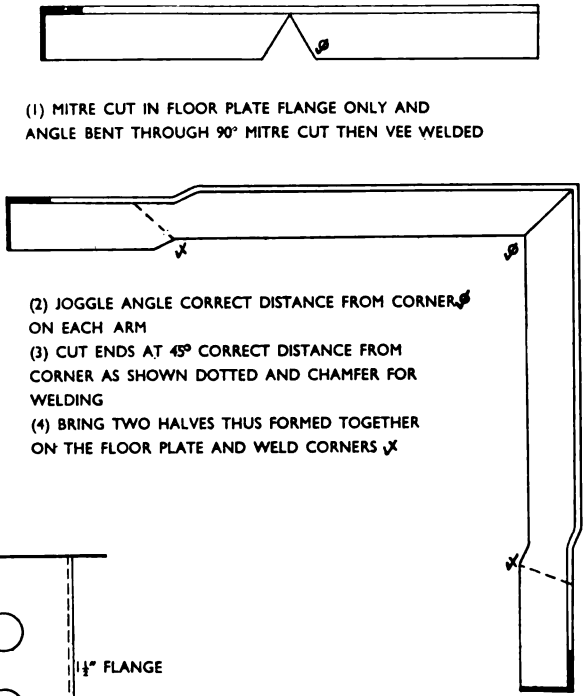
(i) Welded non-W-T. frame


3"x 3"x 6.5 LBS.
12 lbs. PLATE LAPWELDED TO ANGLE ALL ROUND
10 LBS. FLANGED BRACKET WELDED TO FRAME AND I.B. UNDER HEEL BRACKETS OF MAIN MACHINERY SPACE BULKHEADS (ELSEWHERE FLAT BAR ONLY 3"x ½")
3½"x 3"x 7.8 LBS

(ii) Welded O.T. and W-T. frames



Section


(1) MITRE CUT IN FLOOR PLATE FLANGE ONLY AND ANGLE BENT THROUGH 90° MITRE CUT THEN VEE WELDED
(2) JOGGLE ANGLE CORRECT DISTANCE FROM CORNER ON EACH ARM
(3) CUT ENDS AT 45° CORRECT DISTANCE FROM CORNER AS SHOWN DOTTED AND CHAMFER FOR WELDING
(4) BRING TWO HALVES THUS FORMED TOGETHER ON THE FLOOR PLATE AND WELD CORNERS

(iii) Method of making frame angles

Fig. 92. Transverse framing in double bottoms

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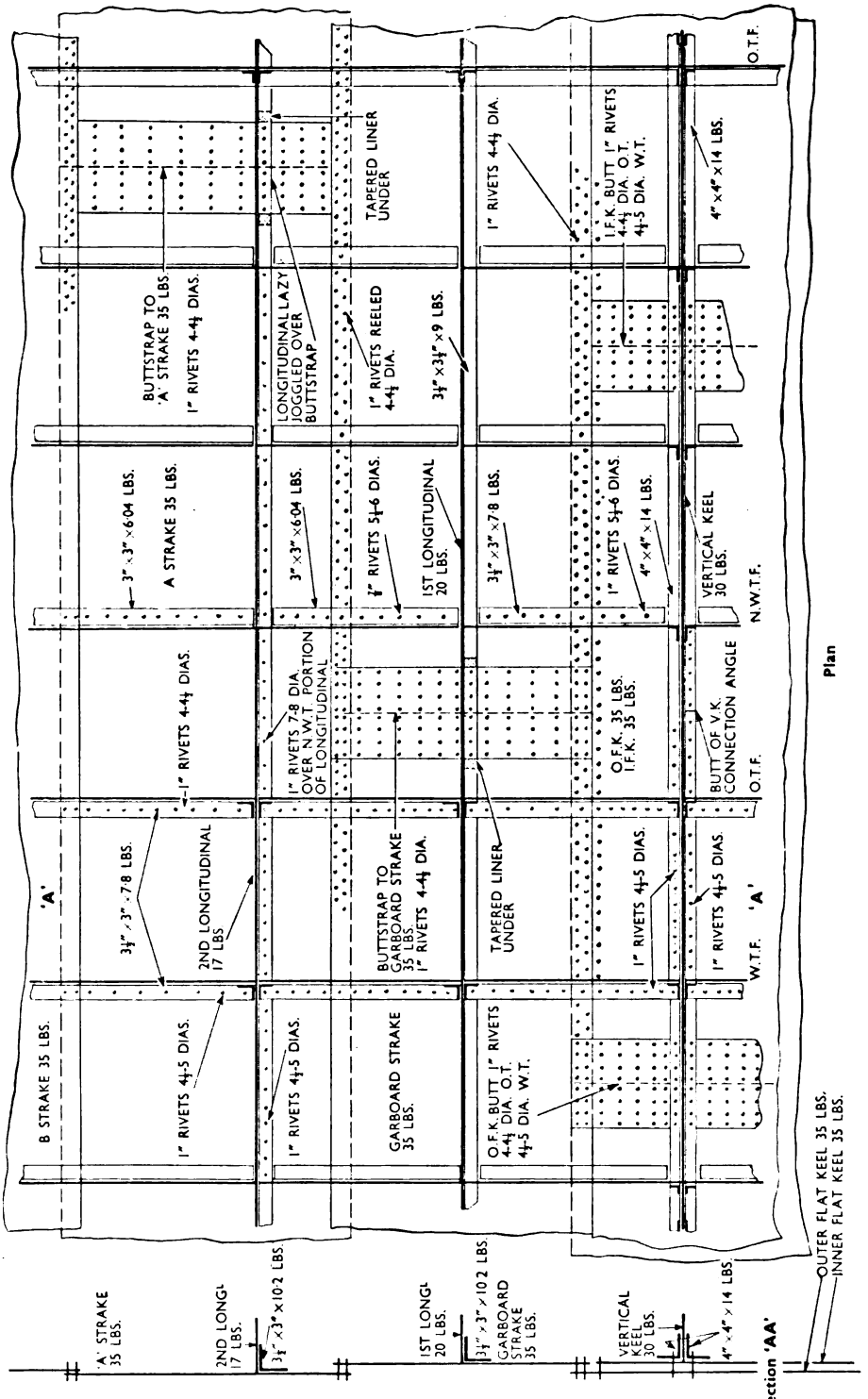
B STRAKE 35 LBS.
'A'
A STRAKE 35 LBS.
BUTTSTRAP TO 'A' STRAKE 35 LBS.
LONGITUDINAL LAZY JOGGLED OVER BUTTSTRAP
TAPERED LINER UNDER
1" RIVETS 4-4¼ DIAS.
3½" × 3" × 7·8 LBS.
3" × 3" × 6·04 LBS.
1" RIVETS 7-8 DIA. OVER N.W.T. PORTION OF LONGITUDINAL
1" RIVETS 5¼-6 DIAS.
1" RIVETS REELED 4-4¼ DIA.
3½" × 3½" × 9 LBS.
1" RIVETS 4-4¼ DIA.
1" RIVETS 4½ DIAS.
2ND LONGITUDINAL 17 LBS
1ST LONGITUDINAL 20 LBS.
BUTTSTRAP TO GARBOARD STRAKE 35 LBS. 1" RIVETS 4-4¼ DIA.
TAPERED LINER UNDER
O.F.K. 35 LBS. I.F.K. 35 LBS.
4" × 4" × 14 LBS.
VERTICAL KEEL 30 LBS.
I.F.K. BUTT 1" RIVETS 4-4¼ DIA. O.T. 4½ DIA. W.T.
O.T.F.
N.W.T.F.
W.T.F.
'A'
GARBOARD STRAKE 35 LBS.
O.F.K. BUTT 1" RIVETS 4-4¼ DIA. O.T. 4½ DIA. W.T.
BUTT OF V.K. CONNECTION ANGLE
Plan
'A' STRAKE 35 LBS.
2ND LONGL 17 LBS.
3½" × 3" × 10·2 LBS.
1ST LONGL 20 LBS.
3½" × 3" × 10·2 LBS.
GARBOARD STRAKE 35 LBS.
VERTICAL KEEL 30 LBS.
4" × 4" × 14 LBS.
OUTER FLAT KEEL 35 LBS.
INNER FLAT KEEL 35 LBS.
Section 'AA'

Fig. 93. Outer-bottom plating

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In the way of barbettes and gun mountings the design of the general structure is decided by two main requirements in addition to that of general strength. First, that no change of form must occur in the ring bulkhead or other support to the roller path, because this might cause jamming of the training gear or bring it out of alignment with other mechanisms ; and secondly, that the stresses set up by gunfire must be evenly distributed throughout the structure to prevent any local failure.

To achieve these requirements special consideration must be given to the disposition and strength of longitudinal deck girders, the placing of pillars in conjunction with them and with existing bulkheads, and any requirement for stiffening of frames and beams in the vicinity. The deck girders are usually built up of plates and sections, and are slotted to allow the beams to be passed through them. Sometimes, in addition, deep web frames are built up at intervals of three or four frame spaces.

Outer Bottom

The outside shell plating affords a watertight skin and contributes largely to the structural strength of the ship. Its weight forms a large proportion of the total weight of the hull and in this respect considerable economy has been effected by the use of high quality steels. It is subjected to two main straining actions, *i.e.*, the pressure of the water on its outer surface and a longitudinal bending action.

The pressure of the water, which varies with the depth and motion of the ship, is a comparatively steady force, but the longitudinal stresses set up by bending action vary considerably with the type of ship and the position in the ship, as already described, and also with the pitching of the ship in a seaway. The thickest strakes are worked over the flat bottom, at the turn of bilge, and at the top of the section each side. The uppermost strake each side is called the sheer strake and is erected as soon as possible during building to hold the hull to its required form. The thickness of the plating is decreased towards the ends consistent with its position in relation to the neutral axis. Relatively thicker plating is required at various positions to take up local stresses, and doubling plates are sometimes worked to present a flush surface, *e.g.*, where the anchors are liable to chafe.

In riveted structures it is essential so to dispose the butts of plating that they do not form a line of weakness in the hull. When arranging the " shift of butts " in the outer bottom, account is therefore taken of the disposition of the butts of the inner bottom plating, vertical keel, and longitudinals (see Fig. 93). Generally speaking, the plates are worked on the " raised and sunken " system, the frames being " joggled " (*i.e.*, grooved or bent) to provide as flat a joint as possible to avoid having to fit liners. Behind armour or side protection the plating is joggled to present a flush outer surface.

Inner Bottom

In ships fitted with a double bottom the inner bottom plating in conjunction with the outer bottom encloses a shallow space called the double bottom, which is divided into a large number of compartments by the longitudinals and transverse frames. Most of these compartments are used as tanks for the stowage of oil fuel and reserve feed water, the remainder being constructed as watertight compartments.

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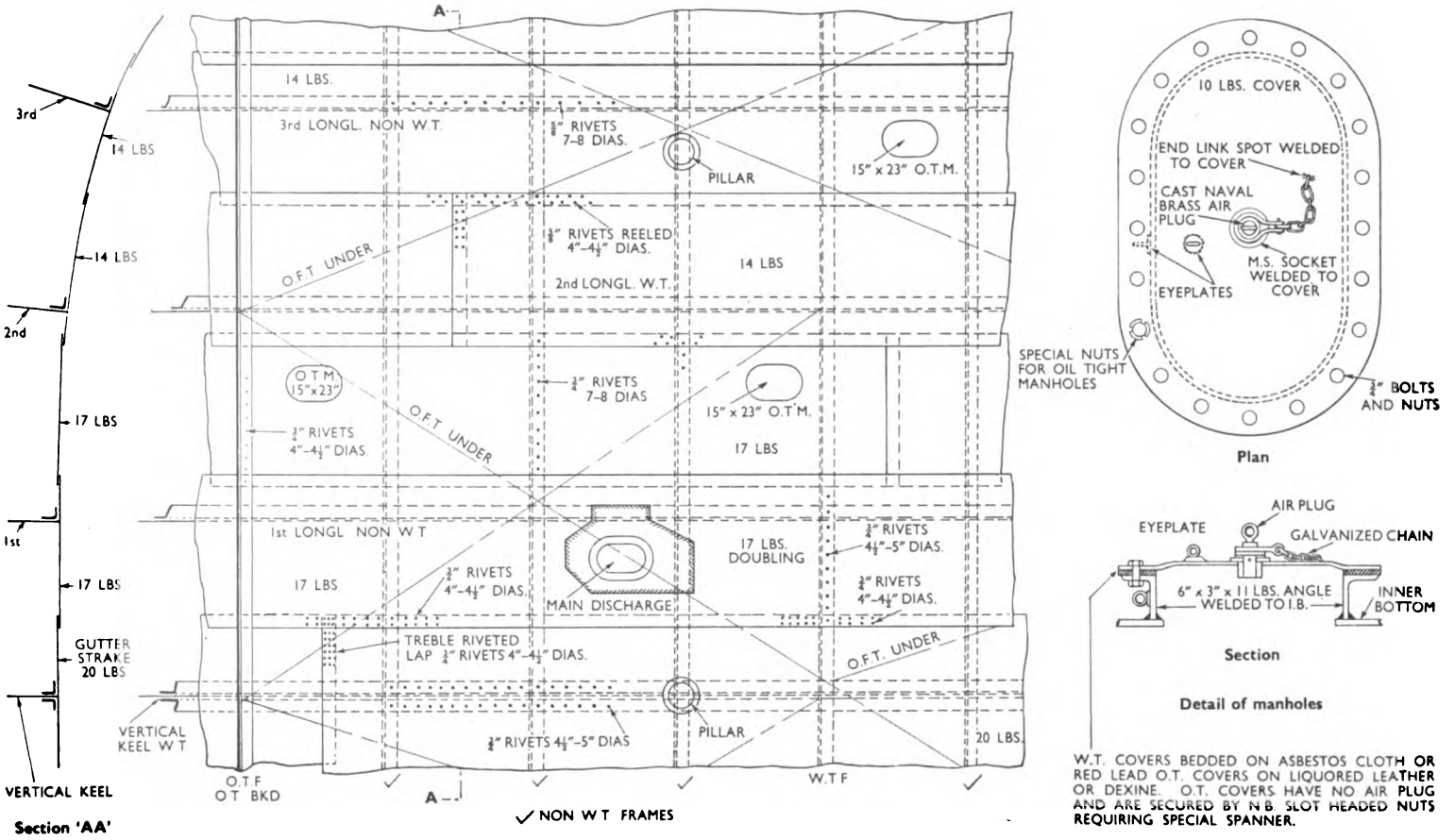

Fig. 94. Inner-bottom plating—cruiser

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The inner bottom plating may be regarded as an inner skin, the primary function of which is to maintain the watertightness of the ship if the outer bottom plating is damaged in any way, by grounding, for example. It is made watertight or oiltight according to the use to which the compartments underneath are put, and it extends throughout the length of the machinery spaces, and in some vessels beyond them. The provision of watertight flats towards the ends of the ship virtually constitutes a continuation of the inner bottom proper. Being worked continuously it contributes to the longitudinal strength of the ship, and as in the bottom plating the butts must be well shifted (see Fig. 94).

The breadth to which the inner bottom extends varies with the class and type of ship. In recent cruisers it is carried round, more or less parallel with the outer bottom, and up as far as the lower deck, (see Fig. 89) but in capital ships and aircraft carriers it extends only to the main longitudinal bulkhead abreast the engine and boiler rooms.

At the ends of the inner bottom continuity of strength is obtained by carrying on the gutter strake and the strakes over the longitudinals for a short distance, the plates being tapered gradually in width and forming brackets for the longitudinals.

Transverse frames or longitudinals separating one oiltight compartment from another need only to be made watertight, but reserve feed tanks are separated from adjacent oil fuel tanks by an oiltight air space to eliminate the risk of oil fuel leaking into the reserve feed water.

Access must be provided to all compartments in the double bottom to facilitate periodical examination of the bottom plating and framing. Two access manholes are provided for each watertight or oiltight compartment, and placed as far as possible in opposite corners to provide good ventilation for anyone working in it(see Fig. 94). The manhole covers are bolted, and bedded with suitable jointing material, on to heavy coamings, the joint being made oiltight or watertight as necessary. An air plug is fitted in the covers of watertight tanks, so that by unscrewing the plug the air can escape as the tank is filled, this being necessary to ensure that the tank is completely filled and that no undue pressure is brought to bear upon it. No such provision is necessary for oil tanks as they are provided with air escape pipes. Above the turn of the bilge it is not necessary to provide raised coamings and the manhole covers are bolted directly to the inner bottom plating. Slot-headed, naval-brass nuts, which can only be removed with special spanners, are fitted to oiltight manholes.

The reserve feed tanks are fitted with 2-inch air escape pipes led to the underside of the upper deck. Zinc protectors are fitted in these tanks near the mouths of steam, drain, and other pipes, where pitting and corrosion of the plating is likely to occur ; in recent ships the inside surface of the plating is galvanised.

Bulkheads

Besides contributing to the watertight sub-division of the ship, bulkheads fulfil two other important functions :—

(i) they hold the ship to her form and support local loads such as armour decks and gun mountings ;

(ii) main bulkheads contribute largely to structural strength and protect important compartments against underwater explosion.

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When a compartment is flooded the pressure and bending moment on its bulkheads are proportional to its depth below the waterline, and for this reason the lower strakes of deep bulkheads are slightly thicker than the upper strakes.

The plating alone, however, is not sufficiently strong to withstand the water pressure and at the same time maintain watertightness, so the bulkheads must be stiffened by vertical and sometimes horizontal stiffeners to minimise deflection and so prevent leakage. The stiffeners are well bracketed at head and heel.

The foremost main transverse bulkhead, usually about 30 feet from the bow, is called the collision bulkhead. It is continuous to the forecastle deck, and in

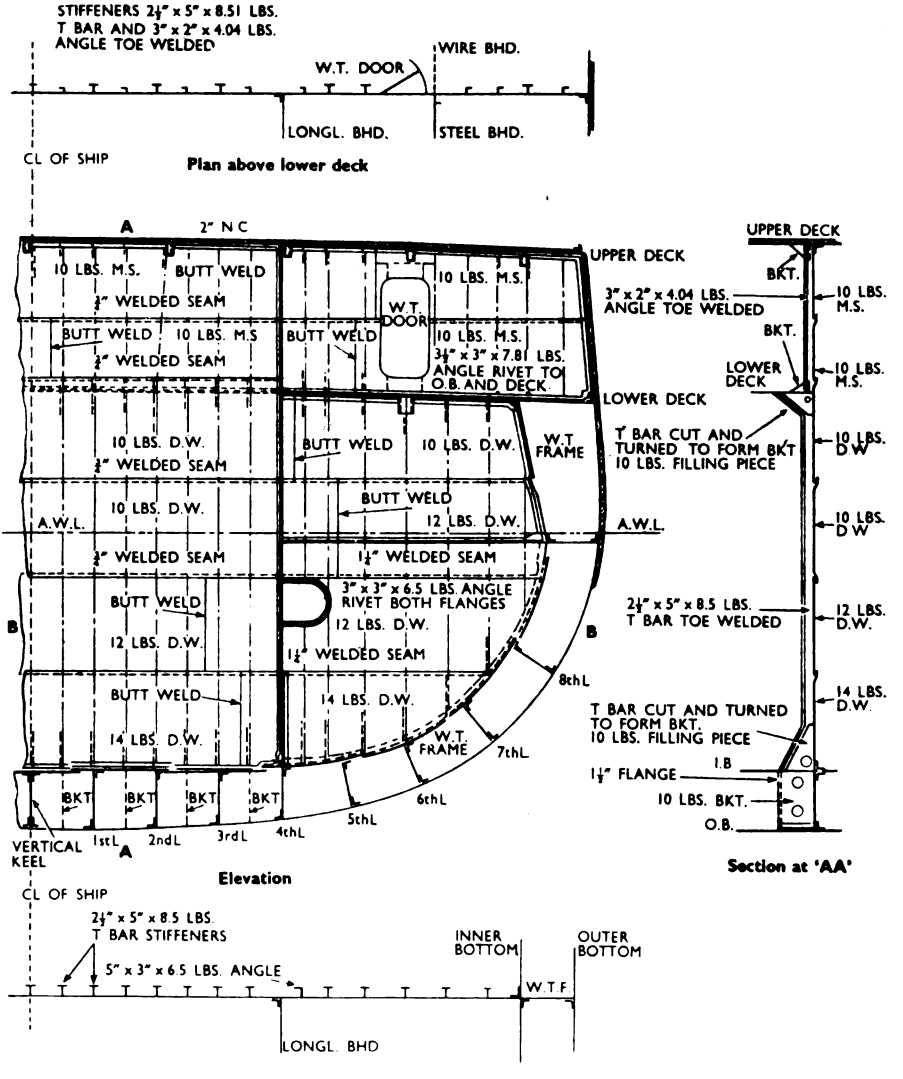

Fig. 95. Main transverse bulkhead—cruiser

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the narrow portion horizontal stiffeners are sometimes worked along the plate edges.

Main transverse bulkheads are worked in horizontal strakes and given vertical stiffening (see Fig. 95). The bulkheads between main machinery compartments extend from the protective deck to the inner bottom, without support from decks or flats ; their plating and stiffening are much heavier, and in riveted bulkheads horizontal stiffeners are sometimes worked along the laps intercostally to the vertical stiffeners. The stiffeners are arranged as far as possible to meet the deck girders and the longitudinals, brackets being worked at head and heel. Where a stiffener comes between longitudinals another flanged bracket is worked between the inner bottom and the nearest transverse frame. Lift trunks and cable passages also serve as stiffeners. Doubling plates are worked where the main steam pipes and propeller shafts pierce the bulkhead, and bulkheads at the after end of the ship in the way of the stern tubes, shaft brackets and the cut-up, are specially stiffened.

The number and disposition of main longitudinal bulkheads depend upon the type of ship. Capital ships are usually provided with deep protection over the midship length in the way of the main machinery spaces. Outside the bulkheads enclosing the main machinery there are usually three longitudinal bulkheads each side, the inner one of which provides protection against underwater explosion, being comprised of two thicknesses of vertical strakes of special quality plating extending from the protective deck to the outer bottom. Outside this protective bulkhead there are two more of lighter construction which form the sides of oil fuel compartments. This system is designed to minimise the effect of an underwater explosion and localise resultant flooding.

Some classes of cruisers are constructed with main longitudinal bulkheads in the way of the machinery spaces, but in others the engine and boiler room extend the full width of the ship to the inner bottom.

The position of other longitudinal bulkheads depends upon the disposition of the various compartments. The most important ones enclose the magazines, and their scantlings of plating and stiffening vary according to whether the magazines are protected separately or by the side armour.

Decks

A ship's decks contribute to her structural strength and form boundaries to oiltight and watertight compartments. In warships all decks are made watertight or oiltight, and the plating is stiffened by the beams and longitudinal girders. The latter are usually deeper than the beams, and are built up of a continuous web plate which is slotted to allow the beams to pass through them, and they have a rider plate or double angles along the lower edge.

The principal decks in a capital ship are the forecastle, upper, main, middle, lower, and platform decks. The forecastle deck extends over the forward part of the ship only ; in recent ships it is omitted, but the term " forecastle " is still retained for the foremost portion of the upper deck. In cruisers there is no main or middle deck, owing to the comparatively small depth of these vessels.

Decks above the waterline are given a transverse " round down," *i.e.*, they have a slightly convex surface to assist any water on them to drain away to the waterways. The main and upper decks are also given a slight " sheer," *i.e.*, their upper surface is longitudinally concave.

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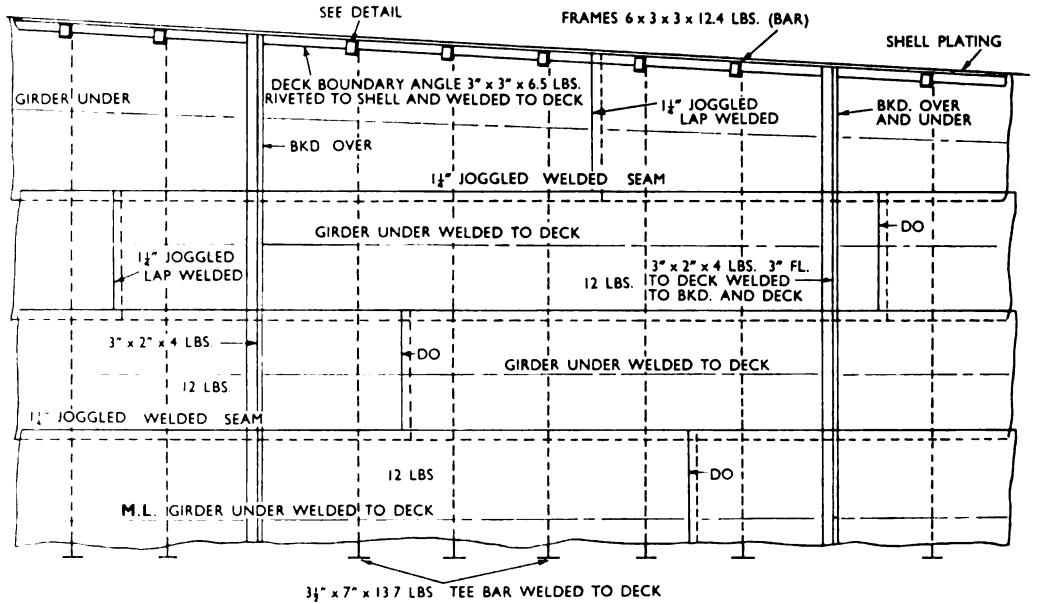
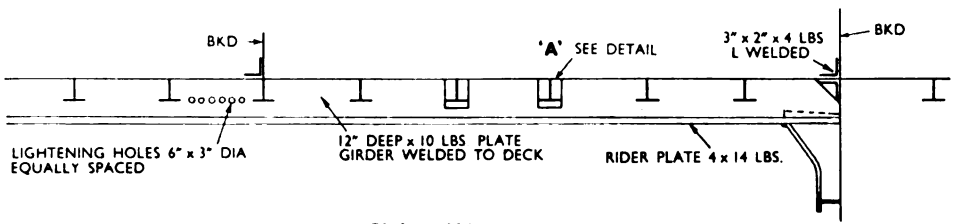
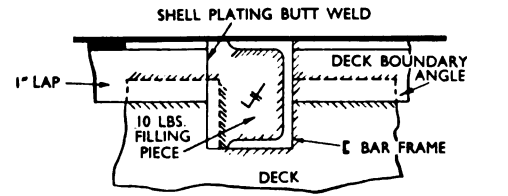

SEE DETAIL
FRAMES 6 x 3 x 3 x 12.4 LBS. (BAR)
SHELL PLATING
GIRDER UNDER
DECK BOUNDARY ANGLE 3" x 3" x 6.5 LBS. RIVETED TO SHELL AND WELDED TO DECK
1¼" JOGGLED LAP WELDED
BKD. OVER AND UNDER
BKD OVER
1¼" JOGGLED WELDED SEAM
GIRDER UNDER WELDED TO DECK
DO
1¼" JOGGLED LAP WELDED
3" x 2" x 4 LBS. 3" FL. TO DECK WELDED TO BKD. AND DECK
12 LBS.
3" x 2" x 4 LBS.
12 LBS.
DO
GIRDER UNDER WELDED TO DECK
1¼" JOGGLED WELDED SEAM
12 LBS
DO
M.L. GIRDER UNDER WELDED TO DECK
3½" x 7" x 13.7 LBS. TEE BAR WELDED TO DECK


BKD
'A' SEE DETAIL
3" x 2" x 4 LBS L WELDED
BKD
LIGHTENING HOLES 6" x 3" DIA EQUALLY SPACED
12" DEEP x 10 LBS PLATE GIRDER WELDED TO DECK
RIDER PLATE 4 x 14 LBS.

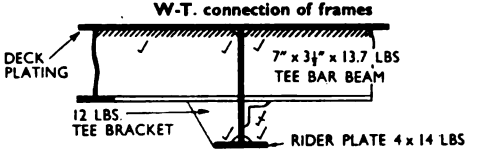
Girder at M.L.



FULL WELD

HOLE CUT IN DECK TO ALLOW PASSAGE OF FRAME

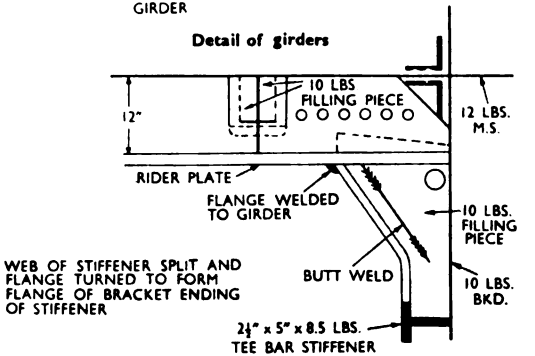
W-T. connection of frames



FULL CONTINUOUS WELD

5½" ANGLE LUG 2½" x 2½" x 4.5 LBS WELDED ALL ROUND TO GIRDER AND LOWER FLANGE OF BEAM OMITTED IF FLANGE OF BEAM FITS WELL WITH HOLE IN GIRDER

Detail of girders


12"
10 LBS FILLING PIECE
12 LBS. M.S.
RIDER PLATE
FLANGE WELDED TO GIRDER
10 LBS. FILLING PIECE
WEB OF STIFFENER SPLIT AND FLANGE TURNED TO FORM FLANGE OF BRACKET ENDING OF STIFFENER
BUTT WELD
10 LBS. BKD.
2½" x 5" x 8.5 LBS. TEE BAR STIFFENER

Detail at 'A'

Fig. 96. Lower-deck plating—cruiser

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When a ship is in a seaway the maximum stresses in the deck plating occur in the outer strakes, and for this reason the scantlings of the plating are usually greatest for the stringer plate and decrease towards the middle-line strake. The main departures from this general rule are around funnels, hatches and other large openings, in the way of local heavy weights such as barbettes, and where additional protection is required.

The uppermost continuous deck, being farthest from the neutral axis of the ship's section and therefore the most highly stressed, is worked as a strength deck, its scantlings being increased by comparison with those of the other decks.

As with outer bottom plating, the butts of deck plating need careful disposition (see Fig. 96). In arranging the shift of butts full account is taken of the butts of the sheer strake, deck openings, and removable plates for installing machinery, etc.

The decks and sides of superstructures, being well above the neutral axis, would be subjected to very severe strain if built continuously throughout their length. For this reason the plating of the deck and sides of the main superstructure is deliberately cut so that a sliding " expansion joint " can be made, as shown in Fig. 97. For an exceptionally long superstructure there may be two expansion joints, but for short superstructures no joint is necessary.

Hatchways and other openings in decks cause loss of strength, to compensate for which it is necessary to fit coamings round the edges of the opening. Deep, heavy coamings are worked in the way of the funnel uptakes in order to provide support for the funnel and to make up for the loss of strength caused by the large opening in the deck ; an inner coaming of the same depth is connected by " U " shaped plates to the outer strength coaming at the corners, and at intervals between. The boiler uptakes and the parts of the funnel over them are bolted to this inner coaming. As the latter is subjected to considerable heat, provision must be made for expansion, and for this purpose the coaming plates are cut short at each end and bolted to the corner " U " plates with special bolts in elongated holes. The intermediate " U " plates are riveted to the inner and outer coamings and permit expansion of the inner coaming to the limits allowed by the elongated holes.

Beams, Brackets and Pillars

The transverse framing is completed by the beams, which act as strong ties and struts to prevent any tendency of the side frames to approach or recede from each other, and at the same time stiffen the decks and assist them to support the loads on them. To resist racking strains and the consequent angular movement between the beams and frames when rolling heavily, these beams must be efficiently connected by brackets. Racking strains induce large bending moments across the corners and it is therefore essential to obtain continuity and depth of section here by fitting triangular-shaped plates between the frame and beam.

Most of the beams for the various decks are of rolled sections, usually channel or I, or tee-bar if welded. Stronger beams are required under thick decks and in the way of side armour and barbettes ; at these places " deep beams " built up of plates and sections are provided, which because of their increased depth, allow a better disposition of the material in the section of the beam, and so increase its moment of inertia and therefore its strength. Where required, deep beams are worked at intervals of four or five frame spaces, and

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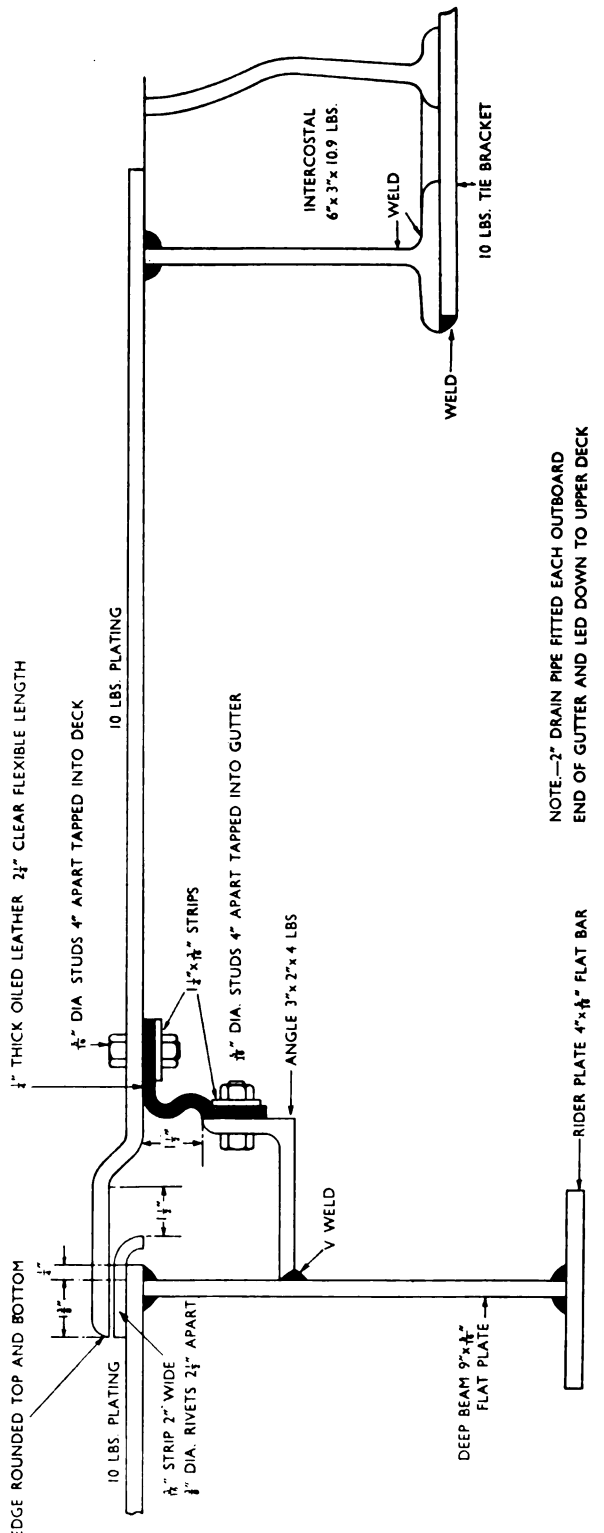
EDGE ROUNDED TOP AND BOTTOM
10 LBS. PLATING
⅜" STRIP 2" WIDE
⅜" DIA. RIVETS 2½" APART
½" THICK OILED LEATHER 2½" CLEAR FLEXIBLE LENGTH
⅝" DIA STUDS 4" APART TAPPED INTO DECK
10 LBS. PLATING
1½"×⅜" STRIPS
⅝" DIA. STUDS 4" APART TAPPED INTO GUTTER
ANGLE 3"×2"×4 LBS
V WELD
RIDER PLATE 4"×⅜" FLAT BAR
DEEP BEAM 9"×⅜" FLAT PLATE
INTERCOSTAL 6"×3"×10.9 LBS.
WELD
10 LBS. TIE BRACKET
WELD
NOTE.—2" DRAIN PIPE FITTED EACH OUTBOARD END OF GUTTER AND LED DOWN TO UPPER DECK

Fig. 97. Section through an expansion joint

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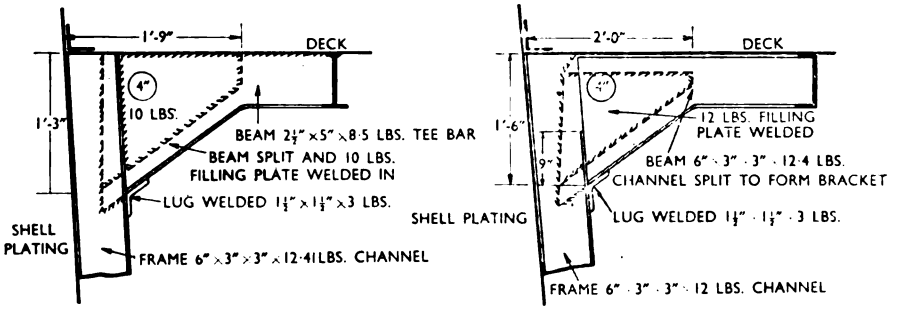
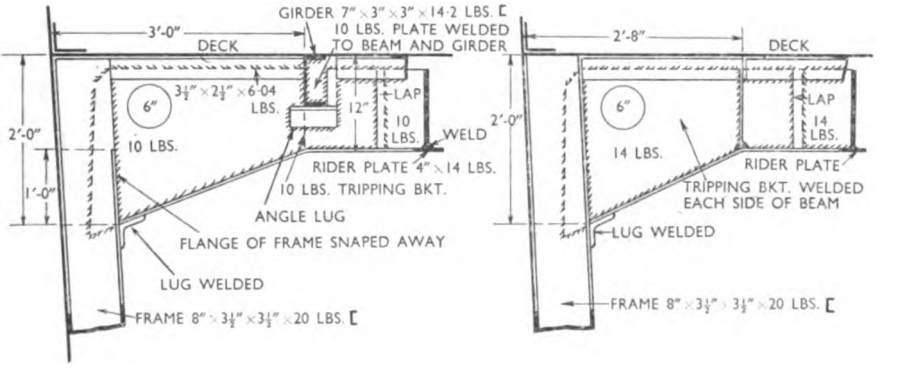
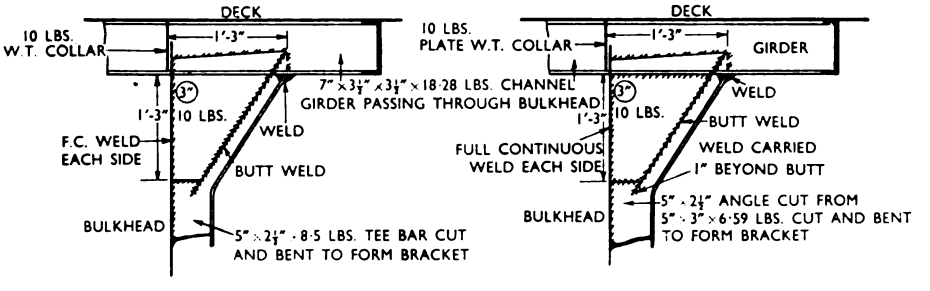

1'-9"
DECK
4"
10 LBS.
1'-3"
BEAM 2½" × 5" × 8·5 LBS. TEE BAR
BEAM SPLIT AND 10 LBS. FILLING PLATE WELDED IN
LUG WELDED 1½" × 1½" × 3 LBS.
SHELL PLATING
FRAME 6" × 3" × 3" × 12·41 LBS. CHANNEL
2'-0"
DECK
4"
1'-6"
12 LBS. FILLING PLATE WELDED
9"
BEAM 6" · 3" · 3" · 12·4 LBS. CHANNEL SPLIT TO FORM BRACKET
SHELL PLATING
LUG WELDED 1½" · 1½" · 3 LBS.
FRAME 6" · 3" · 3" · 12 LBS. CHANNEL

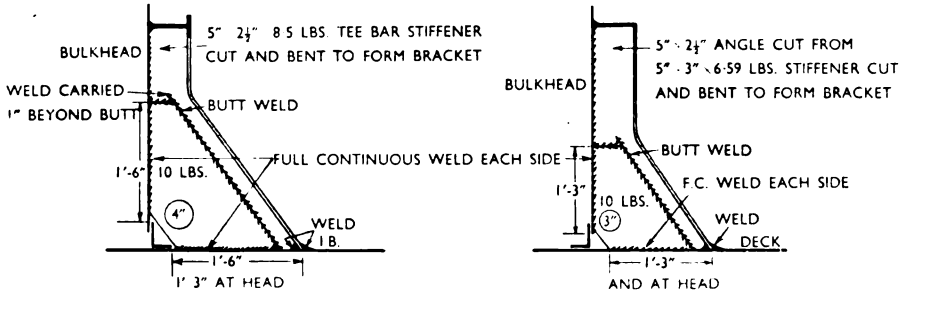
(i) Beam to frame



(ii) Deep beam to frame



(iii) Deck girder or beam to bulkhead stiffener



(iv) Bulkhead stiffener to deck or inner bottom

Fig. 98. Bracketing

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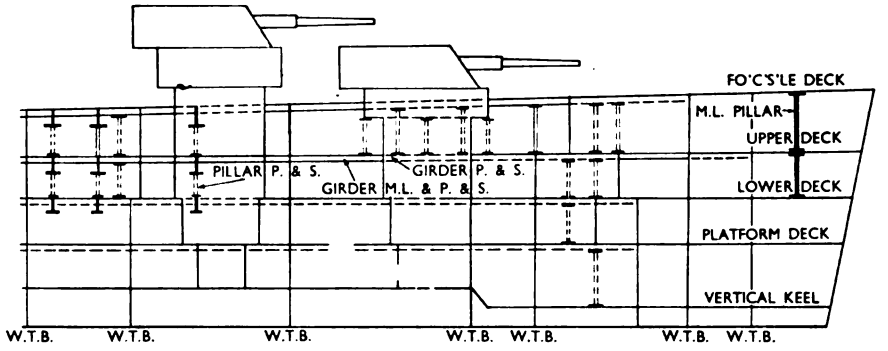
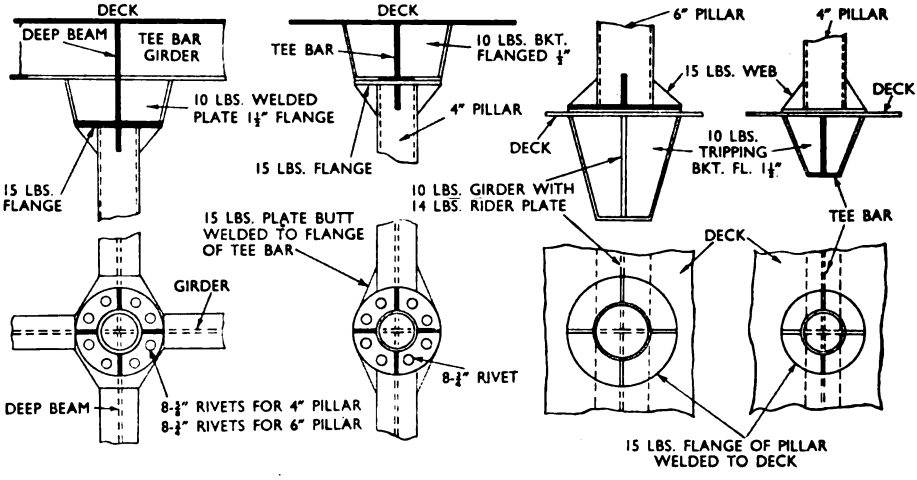
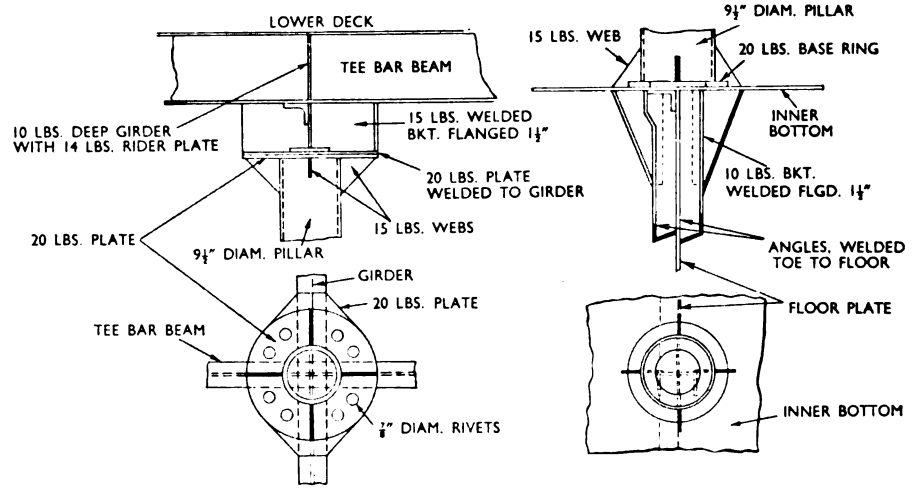


(i) Pillaring in way of forward guns



(ii) Connection of heads and heels of 'tween deck pillars



(iii) Pillars in main machinery spaces

Fig. 99. Pillars

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replace the ordinary beams which would otherwise be in these positions. The ideal beam here is of tee section, and for this electric welding as a means of connection is much more advantageous, because it is a comparatively simple matter to fabricate the beam of a web plate welded direct to the deck, and a rider plate welded to the lower edge of the web plate, the complete beam thus being made symmetrical. This latter point is important because symmetry of section results in the elimination of secondary stresses. Generally speaking, symmetry is not obtained in riveted built-up beams without the use of extraneous connecting angles, and this also applies to bracketing.

A bracket can fail, whether welded or riveted, through the plate buckling along a diagonal line from the corner, and to increase the resistance to this buckling the hypotenuse of the bracket is flanged (see Fig. 98). This tendency to buckle must be carefully considered when deciding whether or not to cut lightening holes in the bracket; if it is decided to cut them they must be correctly positioned. Similar precautions are necessary in positioning lightening holes in deep beams, and their edges must be smoothly cut because any small discontinuity will form what is virtually a notch in the edge which may easily develop into a crack. Particular attention is given to this matter in the transverse frames of double bottoms, the edges of lightening and access holes being stiffened by welding narrow flats round the edges of the holes.

An adequate and well-distributed system of pillaring is essential to assist the bulkheads to support the decks and maintain them at their proper distance apart, and also to maintain the form of the whole structure under all conditions of strain.

Pillars are essential where large areas of deck plating cannot be supported by bulkheads, in the engine and boiler rooms, for example, where sub-division is impossible. In such spaces the pillars are, where possible, heeled on the longitudinals or transverse frames, and where this is not possible, owing to the layout of machinery, for example, special frames are worked in the double bottoms. Elsewhere pillars are fitted with their heads on beams or deck girders and their heels on the steel deck over other pillars or bulkheads, so as to obtain a continuous line of support until a firm foundation is reached (see Fig. 99). All pillars are required to act as ties as well as struts for the decks, and they must therefore not be stepped on wood decks. If a wood deck is fitted it must be cut away so that the heel of the pillar can be fitted to the steel deck.

In the way of barbettes a special system of pillaring is arranged in conjunction with the bulkheads, deck girders and beams, for effectively distributing the stresses set up in the ship's structure by gunfire, including gunblast. Both here and in other parts of the ship subjected to local stresses, bulkheads included in the general arrangement of pillaring must be well stiffened in order to perform the function of pillars, and for this reason it often appears that the stiffening to certain minor bulkheads is unnecessarily heavy.

Watertight Sub-division

Fundamentally a ship is made seaworthy by virtue of her buoyancy and stability, and in the event of damage the preservation of these properties by adequate sub-division of the ship into a number of separate watertight compartments is an essential feature of design.

To preserve her buoyancy, a considerable volume of the ship above the waterline must be watertight, so that loss of buoyancy due to flooding of compart-

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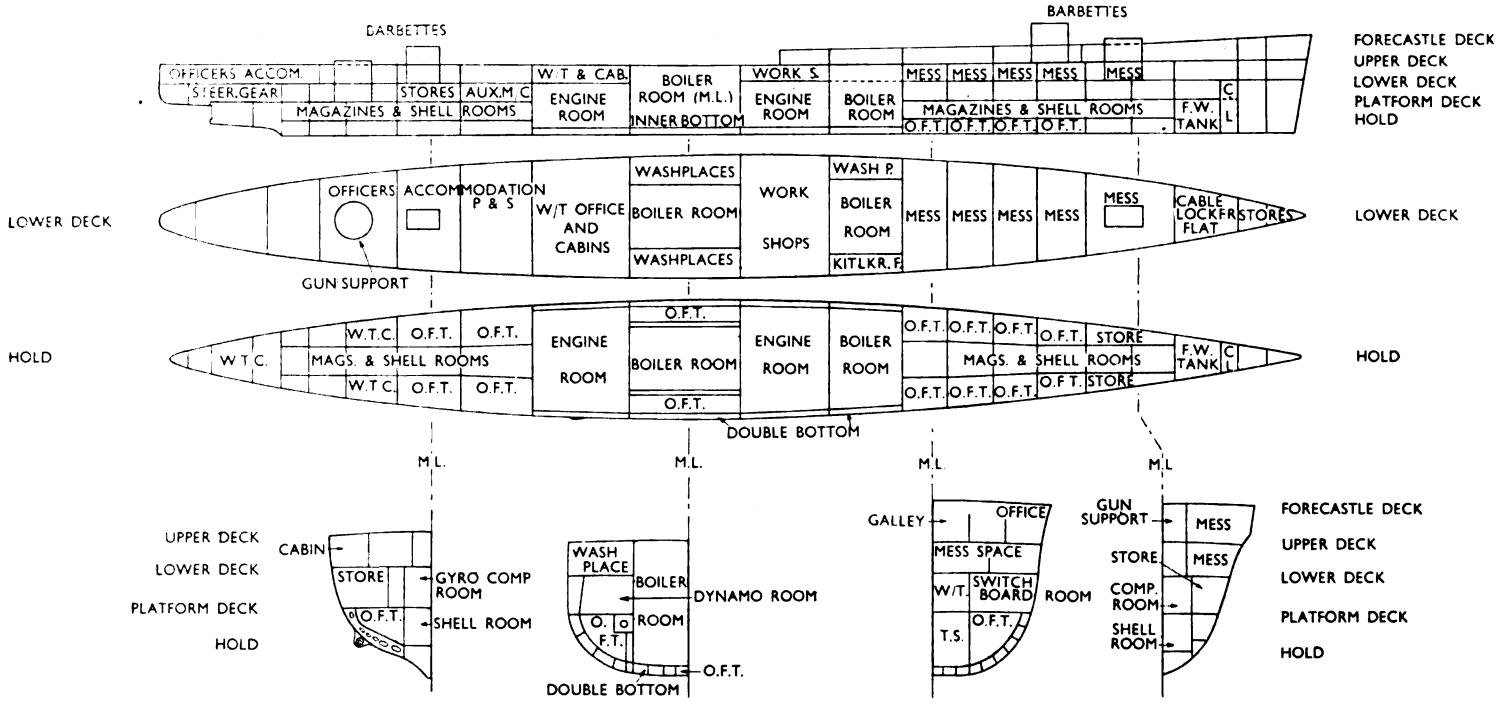

SECTIONS TO LARGER SCALE

Fig. 100. Watertight sub-division—cruiser

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ments below water level is counteracted by a gain of buoyancy above the original waterline. This watertight volume above the waterline is termed the " reserve of buoyancy," and in warships it may be as much as the watertight volume below water, *i.e.*, the " displacement " in the undamaged condition.

The stability of a ship is intimately connected with her buoyancy, but it does not follow that her stability will be preserved throughout the time during which her buoyancy is maintained. A loss of buoyancy may well result in a disproportionate loss in stability, and in the ship becoming unstable before losing all her reserve buoyancy. This fact alone, without a detailed explanation of stability, is sufficient to indicate the essential importance of proper sub-division in limiting flooding caused by damage, and also the necessity of minimising deliberate flooding to correct heel or trim caused by damage.

Watertight sub-division of the ship is obtained by the following watertight structures :—

(i) main transverse bulkheads ;
(ii) main longitudinal bulkheads ;
(iii) watertight between-deck bulkheads ;
(iv) decks and watertight flats ;
(v) the double bottom, which is further sub-divided by the watertight longitudinals and transverse frames.

The degree of sub-division is determined, broadly speaking, by the size of the ship and the contents of the compartments. The compartments are split up into as many units as the requirements of efficiency of communications, expenditure in weight, complication and duplication of pumping, flooding and ventilation arrangements, disposition of machinery and fighting equipment, etc., will allow.

When deciding the sub-division of a hull account must also be taken of the heel which could result from the flooding of wing compartments. In small cruisers, for example, the middle line bulkheads are often omitted because the heel due to flooding one side only would too seriously affect the ship's stability and seaworthiness, or be impossible to counteract by counter-flooding.

Battleships, aircraft carriers, and large cruisers are well sub-divided by fore and aft bulkheads. They retain ample initial stability and can be counter-flooded to float upright and continue in action after sustaining severe damage.

Smaller warships have few fore and aft bulkheads. They are designed still to have some initial stability if two main machinery compartments are flooded when the ship is in a light load condition. Considerable care and a true appreciation of the stability situation are necessary if counter-flooding to correct heel is resorted to.

It will be seen from Fig. 100 that the largest spaces in a warship are the machinery spaces, and that towards both ends of the ship the size of the compartments decreases. This is the result partly of the form of the ship and partly intentional design, and it has the advantage of minimising the effect on the trim of the ship of damage to compartments near her bow and stern.

Vertical sub-division is provided by the decks, their number depending on the size of the ship. Amidships the height of the lowest continuous deck is decided by the height required for her propelling machinery. In small vessels this deck is the uppermost watertight deck, and in larger ships there may be one or more watertight decks above it. The number of decks outside the

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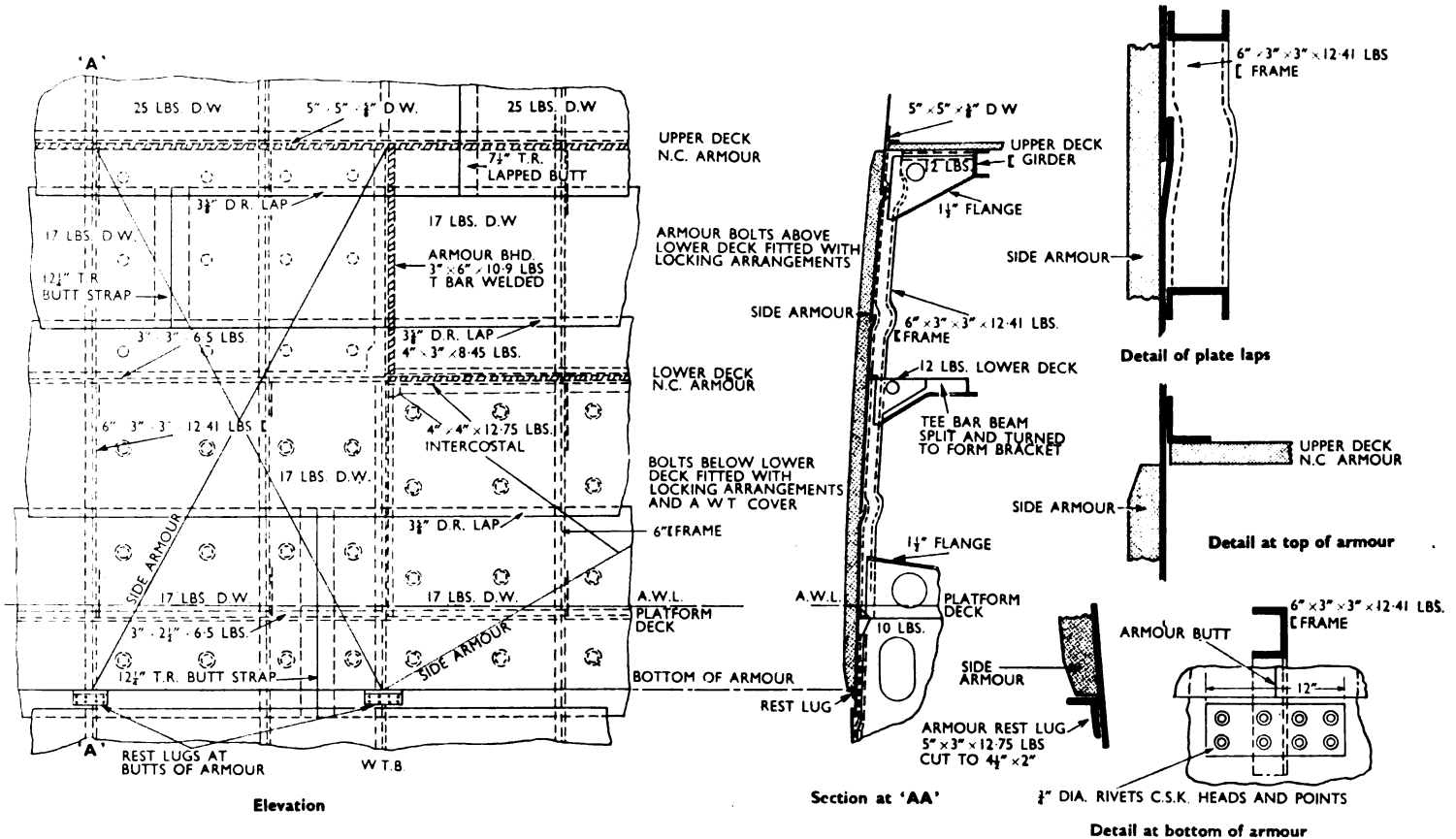
'A'
25 LBS D.W
5" × 5" × ⅜" D.W.
25 LBS. D.W
7½" T.R. LAPPED BUTT
3⅜" D.R. LAP
17 LBS. D.W
17 LBS. D.W.
ARMOUR BHD. 3" × 6" × 10·9 LBS T BAR WELDED
12¼" T.R. BUTT STRAP
3" 3" 6·5 LBS
3⅜" D.R. LAP 4" × 3" × 8·45 LBS.
6" 3" 3" 12·41 LBS
4" × 4" × 12·75 LBS. INTERCOSTAL
17 LBS. D.W.
3⅜" D.R. LAP
6" ⊏ FRAME
SIDE ARMOUR
17 LBS. D.W.
17 LBS. D.W.
3" 2½" 6·5 LBS.
12¼" T.R. BUTT STRAP
SIDE ARMOUR
'A'
REST LUGS AT BUTTS OF ARMOUR
W.T.B.
Elevation
UPPER DECK N.C. ARMOUR
ARMOUR BOLTS ABOVE LOWER DECK FITTED WITH LOCKING ARRANGEMENTS
LOWER DECK N.C. ARMOUR
BOLTS BELOW LOWER DECK FITTED WITH LOCKING ARRANGEMENTS AND A W.T. COVER
A.W.L.
PLATFORM DECK
BOTTOM OF ARMOUR
REST LUG
5" × 5" × ⅜" D.W
UPPER DECK ⊏ GIRDER
2 LBS
1½" FLANGE
SIDE ARMOUR
SIDE ARMOUR
6" × 3" × 3" × 12·41 LBS. ⊏ FRAME
12 LBS. LOWER DECK
TEE BAR BEAM SPLIT AND TURNED TO FORM BRACKET
1½" FLANGE
A.W.L.
PLATFORM DECK
10 LBS.
SIDE ARMOUR
ARMOUR REST LUG 5" × 3" × 12·75 LBS CUT TO 4½" × 2"
Section at 'AA'
6" × 3" × 3" × 12·41 LBS ⊏ FRAME
Detail of plate laps
UPPER DECK N.C ARMOUR
SIDE ARMOUR
Detail at top of armour
6" × 3" × 3" × 12·41 LBS. ⊏ FRAME
ARMOUR BUTT
12"
¾" DIA. RIVETS C.S.K. HEADS AND POINTS
Detail at bottom of armour

Fig. 101. Plating and framing behind side armour—cruiser

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machinery spaces is largely decided by the requirement of reasonable headroom between them.

In all ships the main transverse bulkheads are carried up as high as convenience in communication will allow, in any case well above the waterline and, if possible, up to the uppermost watertight deck.

Secondary sub-division is effected by fitting high sills to watertight doors, deep coamings to hatches, and honeycomb cofferdams in large open mess spaces, the object being to prevent loose water spreading and so to minimise the adverse effect on the ship's stability of the inertia of the free surface of such water.

Maintenance of watertight sub-division, *i.e.*, watertight integrity, is of the highest importance. It is achieved initially, when the ship is built, by good workmanship and specified water or air pressure tests. It can only be ensured on service by the correct maintenance of all watertight fittings, the periodical air tests of compartments, and frequent inspections by the ship's staff.

In submarines good watertight sub-division and integrity follow naturally from the hull being specially built to withstand the pressure of the sea at considerable depths and the effects of depth charging. There are no longitudinal bulkheads, but the pressure hull is divided into several pressure-tight compartments, and the intervening bulkheads are designed to withstand much higher pressures than those specified for surface ships. The end bulkheads must necessarily be designed to take the full sea pressure, and for this reason they are " domed " in recent construction. The foremost interior bulkhead, usually the tube-space bulkhead, is generally stronger than the others and functions as does the " collision bulkhead " in a surface ship. Bulkheads forming boundaries to escape compartments are built to withstand the sea pressure at depths at which escape is possible. All glands and valves in the bulkheads must be designed to withstand the same pressure as the bulkhead.

Armour and Protective Plating

The percentage of the total displacement of warships which can be allocated to protection varies with the type of vessel.

For battleships, which must be capable of withstanding heavy punishment by shell, torpedo or bomb, the weight devoted to armour protection is much higher in proportion to the displacement than in other warships.

Aircraft carriers can depend for protection partly on their own aircraft and their superior speed which may enable them to escape from hostile battleships. A lower standard of protection against above-water weapons is therefore acceptable in these ships.

Cruisers employ their superior speed and manœuvrability to take avoiding action when maintaining contact with larger hostile vessels, rather than rely on their thinner armour and protection. Their weight of armour and protection in proportion to the displacement amounts to about a half of that in battleships, a large part of this weight being expended in providing elaborate local protection to the more vital positions, such as magazines.

In destroyers protection is almost entirely sacrificed to speed and armament, but protective plating is provided as far as possible to vital exposed positions on the bridge and around guns.

Armour Plating

Two types of armour are fitted to warships, cemented and non-cemented.

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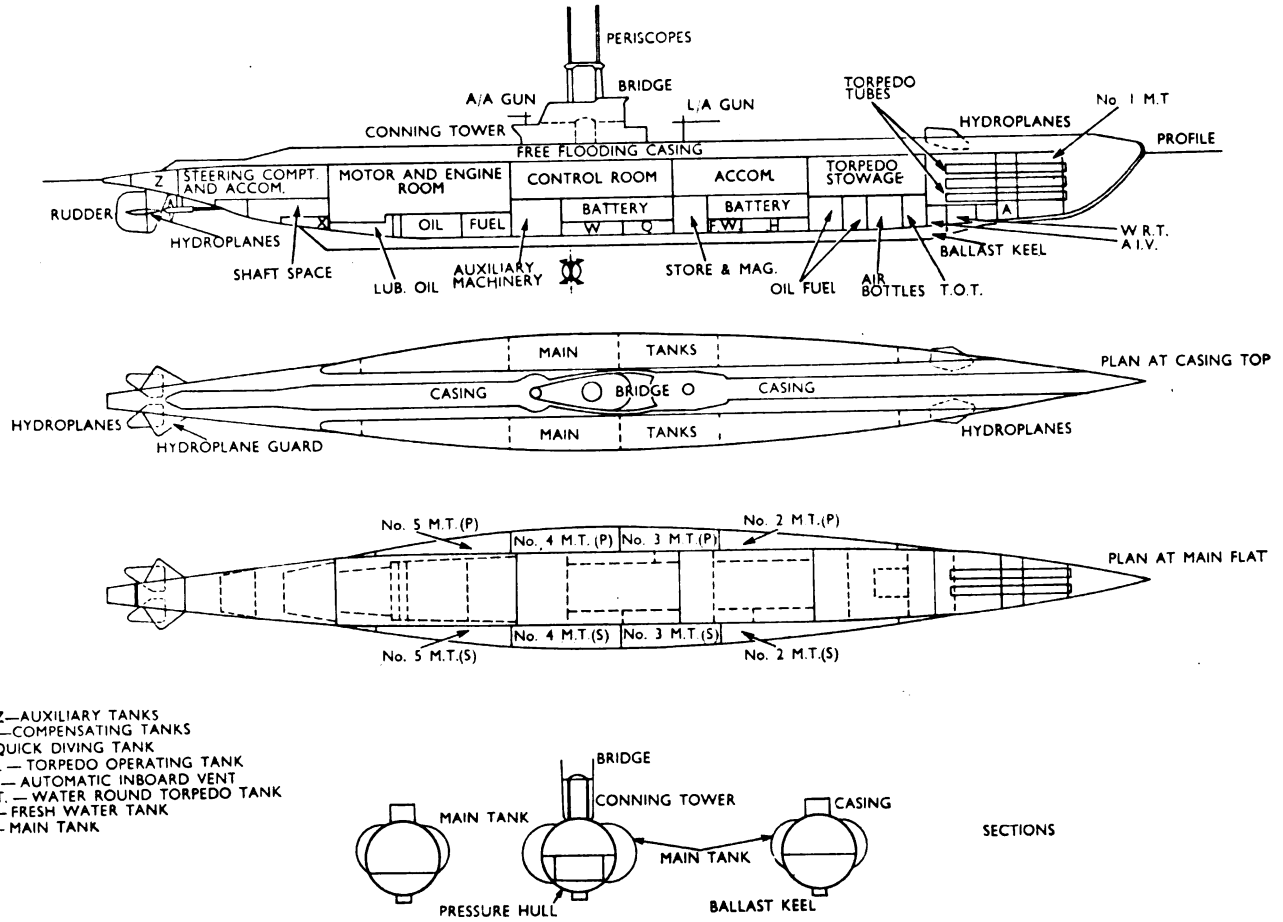

A & Z—AUXILIARY TANKS
HWX—COMPENSATING TANKS
Q — QUICK DIVING TANK
T.O.T. — TORPEDO OPERATING TANK
A.I.V. — AUTOMATIC INBOARD VENT
W.R.T. — WATER ROUND TORPEDO TANK
F.W.— FRESH WATER TANK
M.T.— MAIN TANK

SECTIONS

Fig. 102. General arrangement of a submarine

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Cemented Armour is used on the sides, barbettes and bulkheads of battleships, and on the sides of aircraft carriers and large cruisers. The front surface of the plate is hardened by special heat treatment and the back is specially toughened. The front face cannot be machined after this special heat treatment.

Non-cemented Armour is used on the sides of cruisers and on the decks of battleships, aircraft carriers and cruisers. It is also used for splinter protection in battleships and aircraft carriers. This type of armour can be machined by good shipyard tools.

Protective Plating

Three types of protective plating were fitted during the Second World War to destroyers and other smaller types of warship, and to the bridges of larger warships. They are D.1.H.T. plating, D.K.M. plating and non-magnetic plating, the latter being used on the bridge near the compass. These types of protective plating provide protection against splinters and attack by small arms only.

Owing to the shortage of high quality steel and the heavy demands for these three types of protective plating a substitute called " plastic armour " was developed in this country. It consisted of granite chips embedded in a soft asphaltic matrix, made up into the form of filled trays to facilitate attachment to the sides of superstructures. It afforded reasonable protection against fire from weapons of small calibre, but the degree of protection was not so high, weight for weight, as that obtained from protective plating.

Methods of Securing

Thick armour, cemented or non-cemented, is secured to the sides, bulkheads, or decks, by special armour bolts which are fitted with locking arrangements (see Fig. 101). Below the waterline each bolt is fitted with a watertight cover. Thin armour is secured to decks and bulkheads by countersunk rivets, and protective plating is generally secured by riveting.

Submarines

The design and construction of submarines differ in several important respects from those of surface ships, as is shown in Figs. 102 and 103, which show respectively the general layout and a midship cross-section of a typical submarine. The framework of the pressure hull is conspicuous by the absence of longitudinal girdering, except for that required to support the main engines and motors, and the main frames are transverse, usually of tee-bar section and welded direct to the hull. The spacing, size, and shape of the frames in relation to the thickness of the hull must be arranged to provide adequate strength for resisting underwater explosion and the pressure of the sea when deeply submerged, and this requires careful calculation and the analysis of experimental data. The resulting longitudinal strength is more than adequate to resist the normal stresses imposed on the vessel when on the surface in a seaway.

The increase in diving depth necessitated by the improved efficiency of detection by asdic requires that the pressure hull should be circular throughout its entire length, have specially shaped " domed " ends, and be constructed of special quality steel. The closest attention to detail of design at discontinuities in this main hull, such as at the torpedo hatch and shaft recesses, is necessary,

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and the number and size of openings for hatches, periscopes, valves, etc., must be kept to a minimum. Much heavier compensation for the loss of strength is necessary at such positions than in surface ships.

Electric welding, now adopted for the entire pressure hull, has greatly facilitated the symmetrical and economical disposition of the material with a consequent improvement in diving depth. The use of radiography to search out defective welding enables full reliability to be placed upon the completed hull.

Economical layout of the main compartments, machinery, and equipment to meet staff requirements inevitably results in the pressure hull being cigar-shaped.

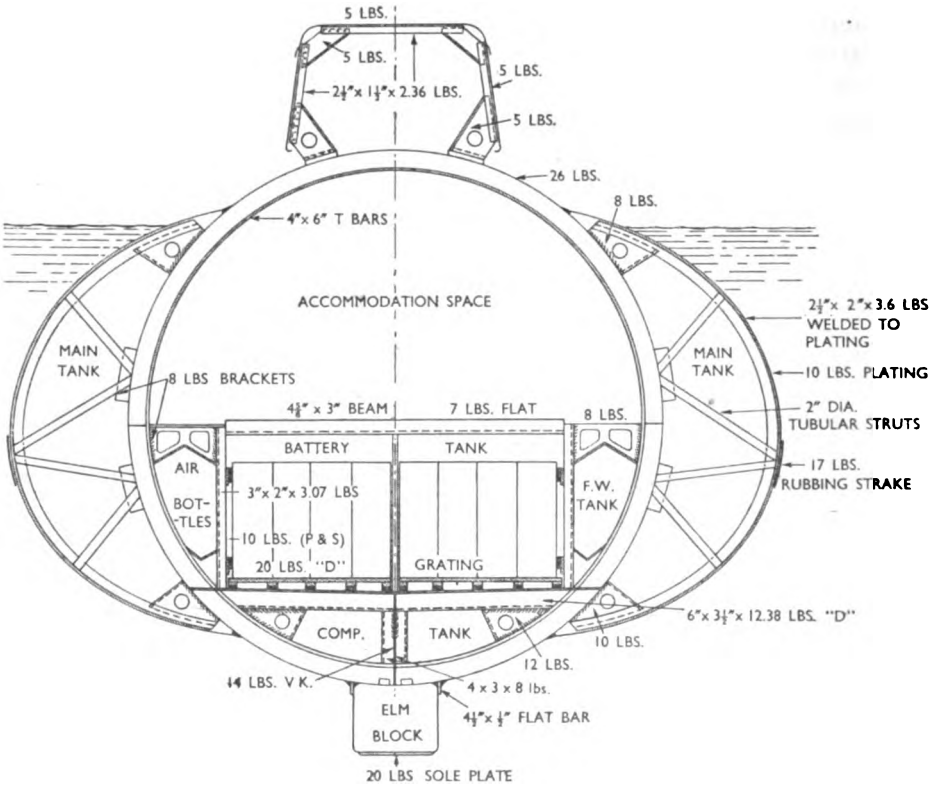

Fig. 103. Midship section of a submarine

The " outer hull," which accommodates the main ballast tanks and external fuel tanks, and fines off the form of the vessel forward and aft, is built outside the pressure hull. Light casings are built around the capstan gear, battery ventilation pipes and other such excrescences outside the hull to provide a streamlined form and so reduce the frictional drag of the hull. The same applies to the bridge structure which encompasses the conning tower, periscope brackets, the bridge and other fittings, and this structure has to be sufficiently high and spacious to facilitate navigation on the surface in adverse weather.

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The reserve buoyancy of a submarine when on the surface, measured by the capacity of the main ballast tanks, is much smaller in proportion to the surface displacement than in surface ships. Broadly speaking, the outer hull is shaped to obtain as streamlined a form as possible. The main tanks and external fuel tanks are usually built in the form of " saddles " on the pressure hull, or as a light outer skin circumscribing the pressure hull. Submarines constructed in the latter manner are known as the " double hull " type.

In all designs adequate stability, both when on the surface and submerged, can usually be achieved only by the provision of special ballast low down in the ship, usually packed in a strongly constructed " ballast keel " which facilitates docking and " bottoming " on the sea bed. Some of the ballast is arranged to be readily portable so that adjustments can be made to the vessel's trim to compensate for changes in weight and moment arising from modifications during refit.

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CHAPTER XV

Pumping and Ventilating Systems of a Warship

THE MAINTENANCE of the various pumping and ventilating systems and the water services of a warship is usually the responsibility of the several technical branches, but the seaman should have a good knowledge of how they work, the uses to which they are put, their capabilities and limitations, and how to get the best out of them. In this chapter the more important details of the pumping and ventilating systems and the fresh and salt water services are described.

PUMPING, FLOODING AND DRAINING SYSTEMS, AND WATER SERVICES

The principal functions of the pumps in the pumping, flooding and draining systems are :—

(i) to keep the bilges clear ;
(ii) to pump out any large quantities of flood water resulting from damage to the hull below the waterline ;
(iii) to supply water under pressure for purposes such as fire-fighting, sanitation and washing decks ;
(iv) to flood certain compartments to correct heel or trim ;
(v) to spray certain compartments to prevent fire or explosion.

Their total pumping capacity varies from about 40,000 tons per hour in a battleship to about 20,000 tons per hour in a cruiser. As a single hole one foot square in the ship's side and 25 feet below the waterline will admit water into the ship at a rate of about 3,500 tons per hour, it will be seen that even if all the ship's pumps could be made to draw in one place they could not cope with the influx of water resulting from extensive damage. For this reason it has for long been the practice when designing large ships to rely on efficient watertight sub-division rather than on pumping power to save a damaged ship.

Types of Pumps

The salient features of the principal types of pumps and ejectors provided in warships are given here.

Main Circulating Pumps.—These are situated in the engine-rooms and are intended mainly for circulating sea water through the condensers, but they can also be used in an emergency for pumping large quantities of water out of the ship. Each pump is fitted with a suction pipe leading to the engine-room bilge, the valve of which is controlled from an adjacent compartment. These pumps work at a comparatively low head of water and discharge under water.

Submersible Salvage Pumps (Fig. 104).—These electrically driven, self-priming, fixed submersible pumps are usually of two types, one having a capacity of 350 and the other of 150 tons per hour. They are provided for dealing with large quantities of water, and are connected to permanent suction

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pipes led to compartments such as magazines, shell rooms, the spirit room, and auxiliary machinery compartments. Because of the low head of water at which the pumps work they are not connected to the firemain.

Emergency Bilge Pumps.—These are fitted in boiler-rooms of large ships and have a maximum capacity of 1,000 tons per hour. Each pump is fitted on the inner-bottom plating, takes its suction from a strum (*i.e.*, a valve box fitted in the outer bottom and having a perforated cover), and discharges overboard through an underwater flap-valve. The pump may be either electrically or turbo-driven, its motor or turbine being fitted on the deck above the compartment in which it is situated and driving the pump by a flexible shaft.

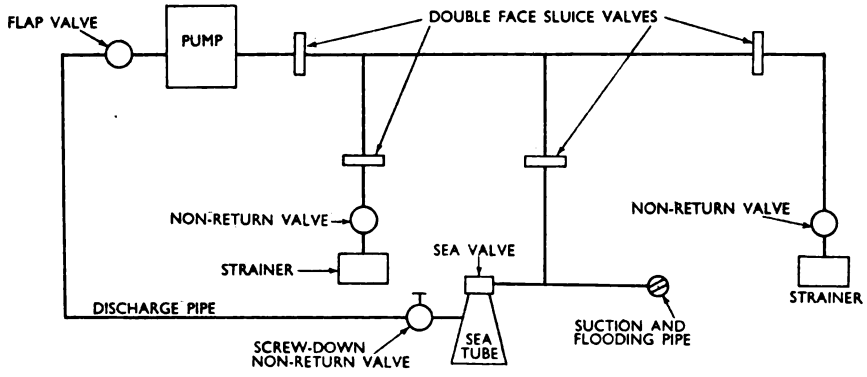

Fig. 104. Typical submersible salvage pump system

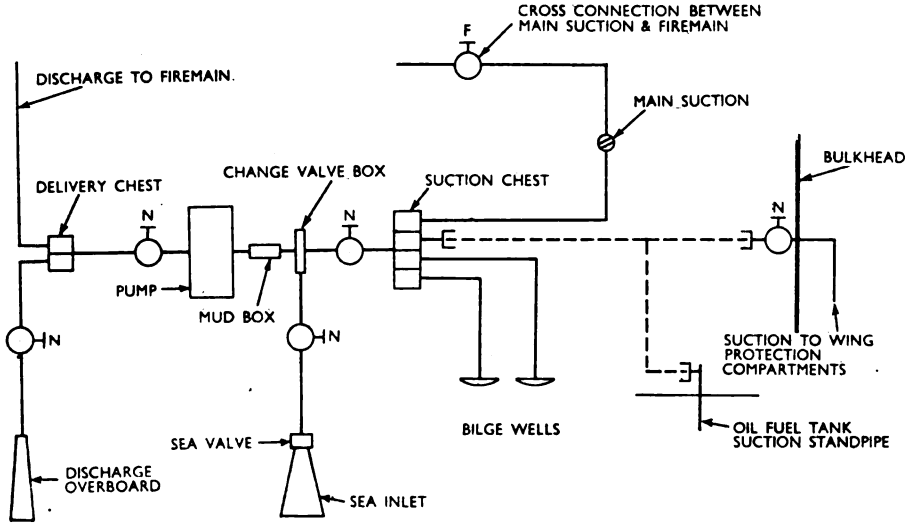

Fig. 105. Typical fire and bilge pump system

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Fire and Bilge Pumps (Fig. 105).—These are fitted in machinery spaces, and are of the self-priming, centrifugal type, and may be either electrically or turbo-driven. Each pump can draw from a seacock in its vicinity, or from a suction chest via a change-valve-box; branch connections are led from the suction chest to bilge wells and fuel tanks, and hose connections are provided for pumping out compartments in the vicinity. The pump discharges into a valve chest from which leads are taken overboard and to the rising main of the firemain. These pumps can therefore be used to pump out the bilges or certain adjacent compartments, or to pump fuel or water from one tank or compartment to another, or to provide water for the firemain. When connected to the firemain the pumps have capacities of from 50 to 75 tons per hour, and when clearing the bilges their capacities are about half as much again. When driven electrically, duplicate electrical supplies are provided.

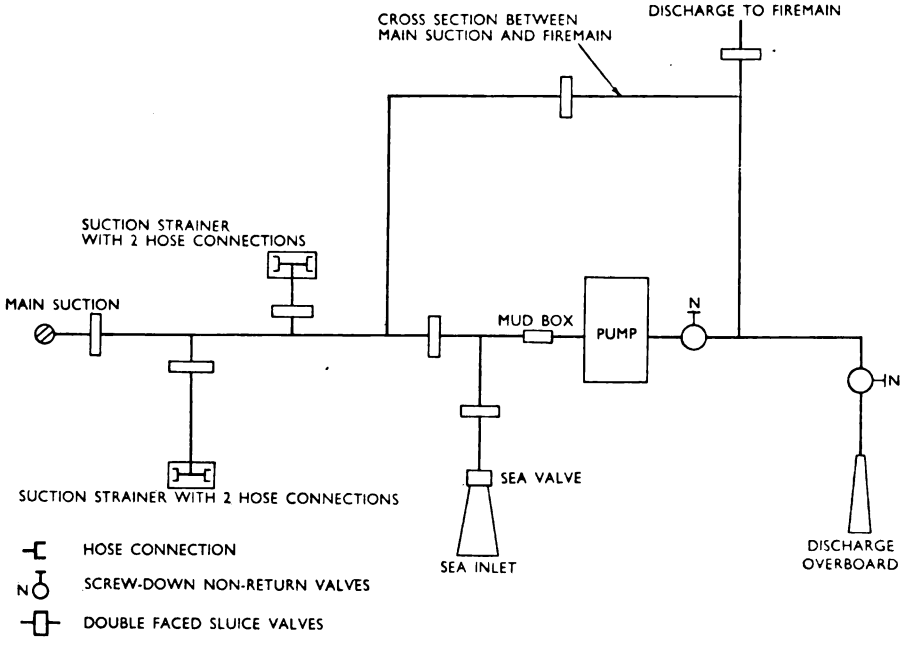

Fig. 106. Typical hull and fire pump system

Hull and Fire Pumps (Fig. 106).—These electrically driven, self-priming pumps are fitted outside the machinery spaces, as low down in the ship as practicable, and can be connected either to the firemain or the bilges. When connected to the firemain they have capacities varying from 20 tons per hour in a destroyer to 75 tons per hour in an aircraft carrier, and when clearing the bilges their capacities are about half as much again. Suction and delivery leads and electrical supplies are in general similar to those of the fire and bilge pumps.

Portable Electric Pumps.—These are provided to augment the permanently fitted pumps, or to replace them if they are damaged, and each has a capacity of about 70 tons per hour. The pump is compact, weighs about 4 cwt., is provided with skids so that it can easily be transported, and can be passed through

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a hatch of two feet square (see Fig. 78 on page 263). It is used for dealing with moderate quantities of flood or bilge water, and can be connected to the ship's suctions for either routine or emergency work.

Portable Diesel Fire and Salvage Pumps.—These are for use when loss of electric power has put the ship's main pumps out of action. The pump weighs about 5 cwt., and can be used for fire-fighting or salvage (see Fig. 77 on page 262). When used for fire-fighting it delivers about 27 tons per hour and takes its suction direct from the sea, standpipes with seacocks being fitted for this purpose, usually one on each side before and abaft the main machinery spaces. When used for salvage work the pump has an output of about 70 tons per hour. The diesel engine of the pump is provided with a hose to lead the exhaust gases to the open air.

Ejectors.—Steam ejectors are fitted in the machinery spaces for ejecting bilge water ; their capacities vary from 40 tons per hour in a destroyer to 300 tons per hour in an aircraft carrier. They are simpler than pumps to operate and maintain but as they use a lot of steam, and hence feed water, their provision and use are limited.

Arrangements for pumping out Compartments

It is the practice when designing large ships to avoid penetrating the main transverse bulkheads below the waterline, and therefore to make the space between each main transverse watertight sub-division of the ship independent and self-contained as regards its pumping arrangements. In most ships, however, a main suction line is fitted which extends nearly throughout the length of the ship, usually below the lower deck. This main suction line is connected to the suction valve boxes of the hull and fire pumps and to one fire and bilge pump in each main machinery space, and from these valve boxes permanent suction leads are taken, or hoses rigged, for pumping out the various compartments.

In modern cruisers the main suction line is in the form of a ring-main fitted with suction standpipes, from which only a few permanent suction leads to compartments are taken, *e.g.*, to the shaft-gland compartments. Most compartments are dealt with by means of hoses rigged between hose connections fitted on the suction valve chests or the main suction line, and on the suction standpipes.

The 70-ton portable pumps mentioned above can be used independently for routine clearance of bilge water, or they can be connected to the main suction line.

Salt Water Service

Each hull and fire pump and each fire and bilge pump discharges into a rising main which is connected to a fore-and-aft main service pipe, usually called the firemain, fitted below the upper deck and extending nearly throughout the ship. In large ships four such mains are fitted, usually under adjacent decks on each side of the ship, and they are cross-connected at intervals and fitted with isolating valves. In modern cruisers (1953) the main service is a ring-main. Isolating valves are fitted at each main transverse bulkhead, and elsewhere as necessary, and in the event of the firemain being damaged, hoses can be rigged from branch connections off the rising mains to connections on the undamaged portion of the firemain. Numerous branches are taken from

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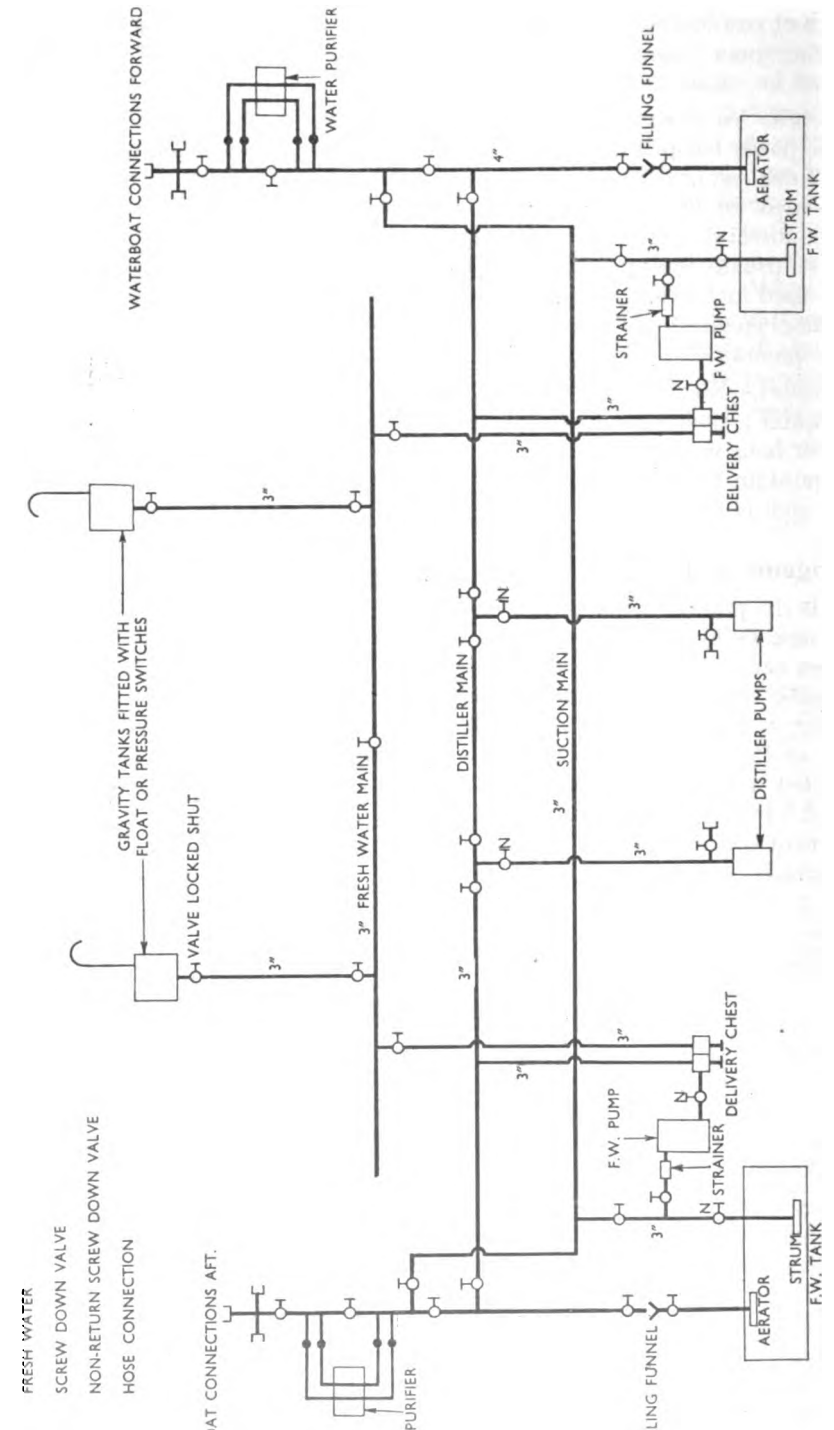

Fig. 107. Typical fresh water service system of a large warship

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the firemain, each having an isolating valve close to the main for supplying the spraying, wash-deck, sanitary, and circulating water systems, and other services.

When the hull and fire pumps, or the fire and bilge pumps, are working on the firemain in normal conditions, water is continually being drawn off for sanitary and other similar services; in action, however, when the firemain is isolated into sections, there may be no "draw-off" and so the water in the pumps would be churned up and overheat them. To obviate this a "leak-off" pipe, which discharges overboard, is fitted to each rising main close to its junction with the firemain.

The firemain is designed for a working pressure of 75 lb. per square inch in modern ships, and 50 lb. per square inch in older ships. As such pressures are too high for flushing purposes in the ship's sanitary system, branches connecting the firemain with the sanitary system are fitted with reducing valves which reduce the pressure to between 20 and 30 lb. per square inch.

Flooding Arrangements

Magazines, shell-rooms and inflammable store rooms are usually flooded direct from the sea, seacocks being provided for the purpose. Where a seacock is used solely for flooding a magazine, only one additional valve is fitted to the flooding pipe, but where the seacock is used for other purposes two valves are fitted. The flooding arrangements of each magazine should be capable of completely flooding it within 15 minutes when fully stowed.

In large ships flooding arrangements are also fitted to certain compartments for the purpose of counteracting heel or trim. In smaller ships such compartments are generally flooded by means of hoses led from hose connections on sea inlets or on the fire and bilge pump delivery valve chest, these being led to other hose connections on the suction standpipes, or direct to the compartment through manholes. Air escapes are fitted to all compartments for which there are flooding arrangements. Where a compartment is flooded from the firemain special care must be taken to ensure that the compartment is not subjected to undue pressure.

Flooding bonnets are provided for the sea inlets of compartments such as magazines so that they can be flooded when the ship is in dry dock. The gratings of the sea inlets are removed and the bonnets secured over the inlets directly the ship is dry-docked and hoses are then rigged between the bonnets and the shore hydrants.

Draining Arrangements

Scuppers are fitted at intervals along the waterways of the upper and forecastle decks, and sometimes at the sides of spaces or compartments on other decks if they are well above the waterline. The scupper pipes are led within and close to the ship's side, and they emerge through it just above the waterline, where they discharge through storm valves of the positive closing type.

In machinery spaces, sumps for collecting bilge water are fitted to the inner bottom. Certain compartments can be drained into adjoining ones which are fitted with suction pipes and so can be pumped out, sluice-valves being fitted wherever a watertight bulkhead is penetrated.

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Bathrooms and washplaces drain into sumps; when situated well above the waterline these drain directly overboard, but when close to the waterline they are cleared by ejectors worked off the firemain.

Spraying Arrangements

Spraying arrangements are fitted in certain compartments such as magazines, where they are usually supplementary to any flooding arrangements, and also in the hangars of aircraft carriers.

Magazines.—Spraying arrangements are usually fitted in magazines of ships larger than destroyers, and they are also fitted in the warhead rooms of destroyers if Q.F. ammunition is stowed in them. The magazine stowages and bulkheads are sprayed from roses fitted in a grid of pipes fed by a lead from the firemain. The controlling valves can be worked from both inside and outside the magazine, the actual positions of the latter depending upon the extent of the armoured protection afforded.

In certain magazines of modern ships (1953) a spraying system only is provided. If such a spraying system is not protected by armour the leads from the firemain to the spraying grid are duplicated, each leading to a different section of the firemain.

Petrol Control Compartments.—These are sprayed from branches led off the firemain, the control valves being worked from inside the compartment and from adjacent lobbies.

Hangars.—The spraying system is fed by electrically driven pumps, each having a capacity of 150 tons per hour and taking its suction from an independent seacock. A ring-main serves a grid of pipes fitted with sprinklers in each hangar section. Cross connections are fitted to enable the ring-main supply to be supplemented by the firemain.

All pumps associated with the hangar spraying system can be started by electric switches which are operated by chains in the access lobbies and at the hangar control positions.

Valves and Gearing

The more important valves can be worked by means of rod gearing from positions in adjacent compartments or from decks above where the actual valve is situated, as well as at the valve itself.

Fresh Water Systems in Large Ships (Fig. 107)

The fresh water storage tanks, which are coated with a special bituminous composition, are connected by permanent piping to water-boat connections fitted on the forecastle and quarterdeck. Each filling pipe is fitted with a water purifier, and the tank is fitted with an overflow pipe just above its crown to release any undue pressure in the pipe or on the structure of the tank. The filling pipes are connected to the distiller main, which runs fore-and-aft and by means of which the after tanks can be filled from the forward water-boat connection, and *vice versa*.

A suction main is usually fitted between the storage tanks and connected to the suction valve boxes so that water can be pumped from, or delivered to any tank by any pump, or delivered to the water-boat connections.

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Pressure of water in the distribution system is maintained either by :—

(i) gravity tanks fitted with electrically operated float or pressure switches for automatic control of the pumps ; or

(ii) air pressure chambers which automatically control the pumps by means of pressure switches.

From the fresh water main, which extends nearly the whole length of the ship, branches are taken to the points of supply, stop-valves being fitted at intervals for isolation purposes.

Ships can seldom store more than a few days' supply of water, and so storage tanks have to be replenished from the ship's distillers during extended periods at sea.

In order to conserve water, self-closing non-concussive taps are fitted in washplaces and bathrooms, and spring-loaded valves are fitted on bathroom showers.

Hot Water Systems (Fig. 108).—Two hot water circulating systems are fitted, one forward and one aft, and they are usually cross-connected. In modern ships (1951) each system consists of a thermostatically controlled, steam-heated calorifier, with flow and return leads run in the form of a loop, the supplies being taken off the flow-pipe. Circulation of the hot water normally depends on convection, but in many systems a booster pump is fitted, usually

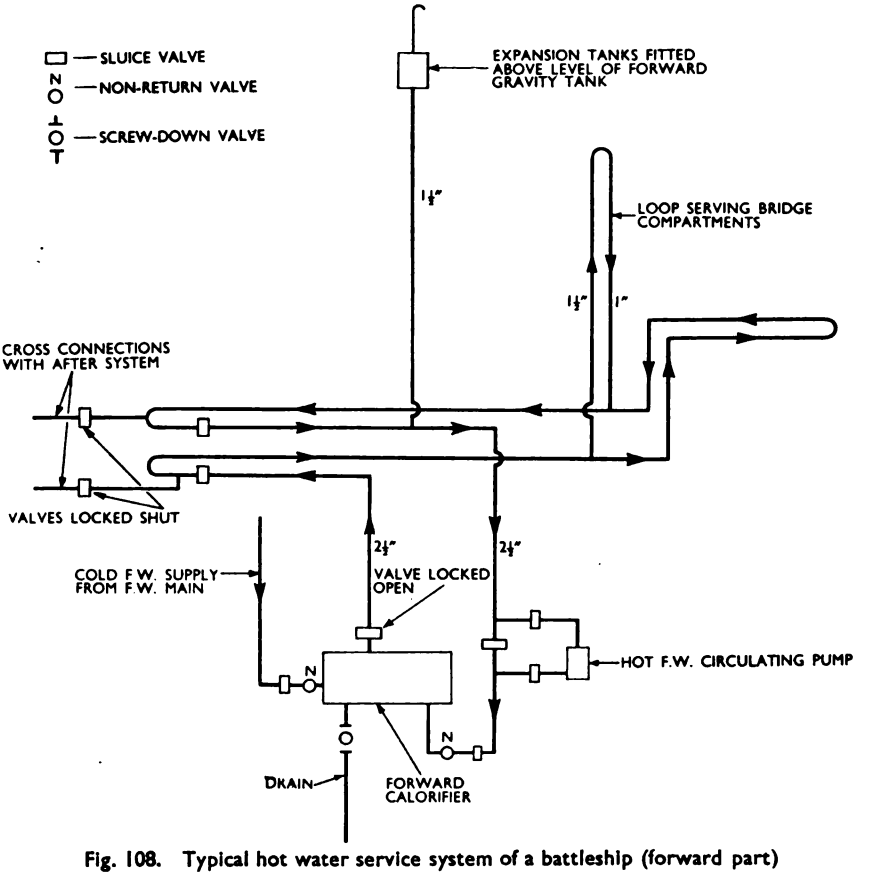

Fig. 108. Typical hot water service system of a battleship (forward part)

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on the return lead, to assist the natural circulation when desired. An expansion pipe is taken from a convenient point on the flow-pipe and terminates in an expansion chamber which is fitted at a slightly higher level than the forward gravity tank.

In older ships a hot water storage tank is incorporated in the system.

Cooled Drinking Water.—Electrically operated, self-contained coolers are fitted in convenient and well-ventilated positions on mess decks for supplying drinking water at a temperature of about 60° F. Supplies to the coolers are taken off the fresh water main.

In most large ships a cooled-water tank worked off the main refrigerating plant is also fitted.

Under tropical conditions one gallon of cooled water per man is considered a reasonable daily requirement.

Fresh Water Systems in Destroyers

In destroyers the old gravity feed system was superseded during the Second World War by a "compression tank" system. The electrically driven pumps are controlled by pressure-operated switches working in association with two compression tanks containing air and water under pressure. One tank is situated forward and the other aft, and they supply, respectively, the forward and after fresh water systems of the ship.

When the pump is working and thus filling the fresh water systems and the compression-tanks with water, the air in the tanks is gradually compressed until it reaches a pressure of about 19 lb. per sq. in., at which pressure the switch automatically cuts out the motor and stops the pump. As water is drawn from the system the air in the tank expands until the pressure gradually drops to about 9 lb. per sq. in., at which pressure the switch starts the pump again and the cycle is repeated.

The tank is charged initially with air under pressure by means of the air-pump incorporated in the main pump. As water absorbs some of the air in the tank it has to be replenished periodically with air. A foot-pump is supplied as an alternative means of charging the tank with air.

In modern destroyers (1953) electric water-heaters are fitted, from which circulating loops are taken. In older vessels hot water is supplied from domestic-type boilers fitted in the galleys.

VENTILATING SYSTEMS

The ventilating system of a warship must be able to function efficiently in all the varieties and extremes of climate which the ship may encounter in both arctic and tropical waters and it must therefore be flexible in operation.

To be efficient, ventilation must not only provide enough pure air for breathing, but it must also produce an atmosphere in which a man can work in comfort. The provision of such an atmosphere depends upon the temperature and humidity of the air outside the ship, its movement and circulation within the compartment to which it is delivered, and the removal from the compartment of used and foul air.

The drier the air the better will be the atmosphere ; a man feels fitter and more comfortable, and so works better, in a dry atmosphere than in a humid one, and this is particularly evident in extreme heat or cold. Movement of the

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air, such as a breeze or a draught, has a cooling effect which is an advantage in hot climates and a disadvantage in cold ones. For reasons which will be seen later, efficient ventilation is more easily effected in arctic conditions than in the tropics.

Ventilation in Arctic Waters

Efficient ventilation in arctic conditions is provided quite simply by incorporating heaters in the ventilation trunking, by supplying no more air than is required to keep the atmosphere in a compartment pure, and by eliminating draughts. The heaters, which are manually controlled and worked by steam, heat the air in the trunking to a temperature of between 60°F. and 65°F., dry bulb, and in the process they dry the air to a certain extent. The speed of the fans is regulated to provide just enough air to the compartment at an air speed of between 20 and 40 feet per minute. Diffusers are fitted to the supply openings of the ventilation trunking in the compartments, to eliminate draughts.

Ventilation in the Tropics

Efficient ventilation in tropical climates is more difficult because the air is usually humid and it is impracticable to cool or dry the large quantities required. Ventilation under such conditions therefore consists mainly in providing compartments with large quantities of air at relatively high speeds in order to keep the atmosphere in them in continual circulation and movement, thus scavenging the compartment of heat and foul air and at the same time providing a breeze. An efficient exhaust system is most necessary to ensure that the air in a compartment is completely changed at frequent and regular intervals, and also to prevent any pressure being built up in the compartment which would reduce the efficiency of the fans. Under these conditions the fans must be maintained in a high state of efficiency because they will be running continuously at full speed.

To determine ventilation requirements in the tropics a scale of temperature known as the " effective temperature " is used. This scale takes into account the dry bulb temperature and the humidity and movement of air in a compartment in comparison with the atmospheric conditions in the open air. Health and efficiency deteriorate when the effective temperature exceeds 86°F.

Meteorological records show that tropical air conditions over the open sea average about 88°F. dry bulb and 80°F. wet bulb, or an effective temperature of 82 to 83°F at low air-speed ; near land and in land-locked waters these temperatures are usually much higher. The mean temperature within the ship, however, is always greater than that of the open air, because the ship herself generates a certain amount of extra heat from her machinery, boilers and galleys, and the men living and working in her give off an amount of heat which varies with their activities. In the tropics there is, therefore, little margin between the effective temperature of the ship and the critical effective temperature of 86°F., but the problem can be solved by lowering the effective temperature within a compartment by passing large quantities of air quickly through it at high speed and eliminating as far as possible any " wild " (*i.e.* unnecessary) heat.

The quantity of air required in a compartment depends upon the heat within it, and for living spaces it is usually between 30 and 35 cubic feet per minute

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per man, and this must be provided at an air speed of between 100 and 300 feet per minute.

The amount of " wild " heat in a compartment can be reduced by :—

(i) lagging steam and hot water pipes, lagging deckheads in compartments directly below the weather decks, lagging the ship's side in side-compartments above the waterline, and lagging bulkheads adjacent to hot compartments ;

(ii) removing hot air from particularly hot places, such as galley ovens and domestic water heaters, by means of special exhaust fans and trunking ;

(iii) cooling the weather decks and the ship's sides by playing water from the firemain on them with wash-deck hoses ;

(iv) switching off all unnecessary electric lighting.

Methods of Ventilation

From the foregoing it will be seen that ventilation requirements for tropical conditions govern the design of the ventilation system of a warship, and the following description deals chiefly with the methods used generally to meet these requirements.

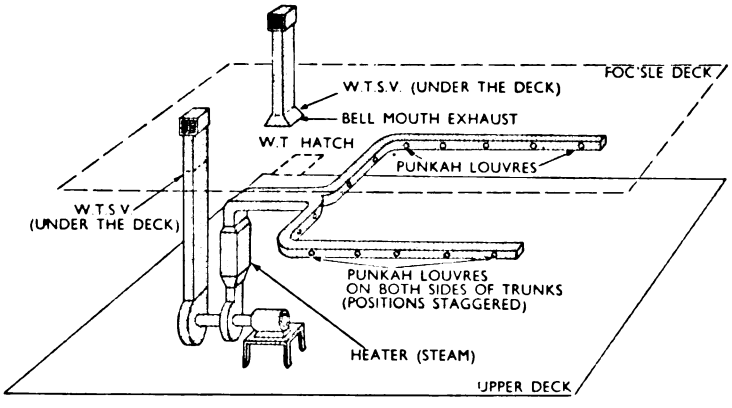

Fig. 109. Typical ventilating system of a mess deck

For general ventilation purposes, compartments and their ventilation arrangements can be grouped into the following four main categories.

(i) Living and working compartments in which no great heat, harmful gases, or smells are generated ; examples are mess decks, workshops not fitted with furnaces, store-rooms in regular use, and offices. Such compartments are provided with a forced supply and a natural exhaust, and the air is led to positions which are normally occupied to ensure that the occupants receive air which is nearly as fresh and clean as the open air. If, however, the compartment is more than one deck below the weather deck, or if the exhaust trunking does not provide a free flow for the used air, a forced exhaust is fitted instead of a natural one.

(ii) Compartments in which heat, smells, or harmful gases are produced ; examples being occupied power-rooms and radar-rooms. Such compartments are provided with a forced exhaust and a natural supply,

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and in addition a small forced supply is directed to positions where the occupants normally work. The exhaust and supply are regulated so that pressure in the compartment is slightly less than the pressure outside it, thus preventing the heat, smells or gases from penetrating into adjacent compartments.

(iii) Compartments in which great heat is generated, such as engine-rooms and galleys. Such compartments are provided with a forced supply and a forced exhaust, so regulated that the rate of supply is slightly less than that of the exhaust to ensure that no hot air escapes into adjacent compartments. The supply is concentrated at positions where the occupants normally work, and to other positions which provide havens into which men can go to obtain relief from the hot air around them. The exhaust is concentrated at the places where most heat is generated, thus ensuring that the overheated air in the vicinity does not escape into other areas and so raise the temperature throughout the compartment.

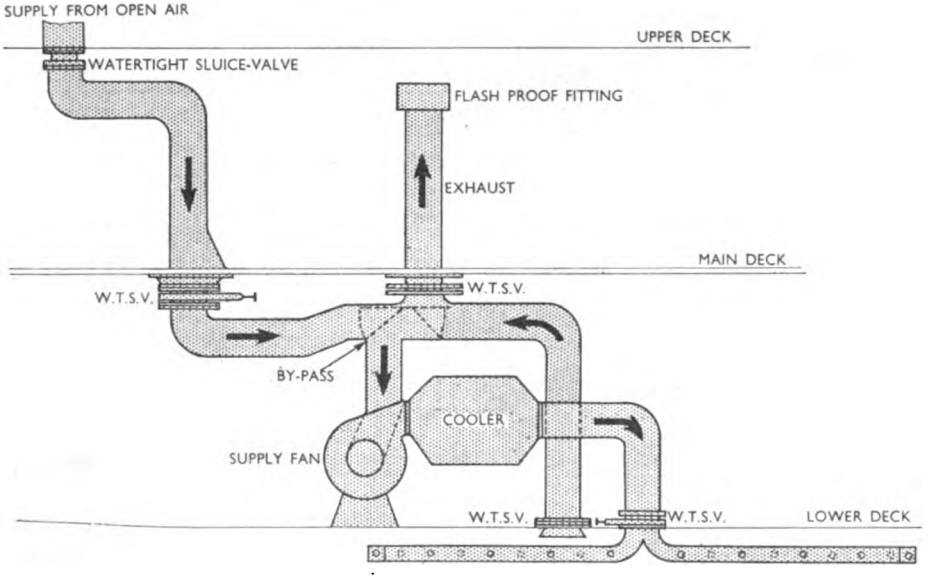

Fig. 110. Typical magazine ventilating and cooling system

Boiler-rooms can be included in this category, but in these compartments only forced ventilation is provided by the powerful forced-draught fans which maintain a comparatively high pressure in them. Some of the incoming air is diverted to the watchkeeping positions, but most is passed round the boilers, thus heating the air before it enters the furnaces and also helping to lag the boilers. The exhaust is by way of the funaces and funnels to the open air.

(iv) Compartments which are infrequently used and which do not require a constant supply of air, such as the sail-locker and unoccupied store-rooms. Such compartments are ventilated only when required, by

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portable air-hoses led from nearby connections specially provided in the permanent ventilation system. It should be borne in mind, however, that these compartments, particularly the sail-locker and certain store-rooms which are seldom entered, require ventilating at regular intervals, and to ensure this a routine for their ventilation should be laid down.

(v) Certain compartments in which heat is generated, or in which considerable numbers of men work, and in which it is essential for the occupants to maintain a high degree of alertness or to perform hard work. Examples of such compartments are action information centres, damage control headquarters and certain magazines. These compartments are air-conditioned because it is not possible in the tropics to provide in them the necessary atmospheric conditions by means of the normal ventilation arrangements.

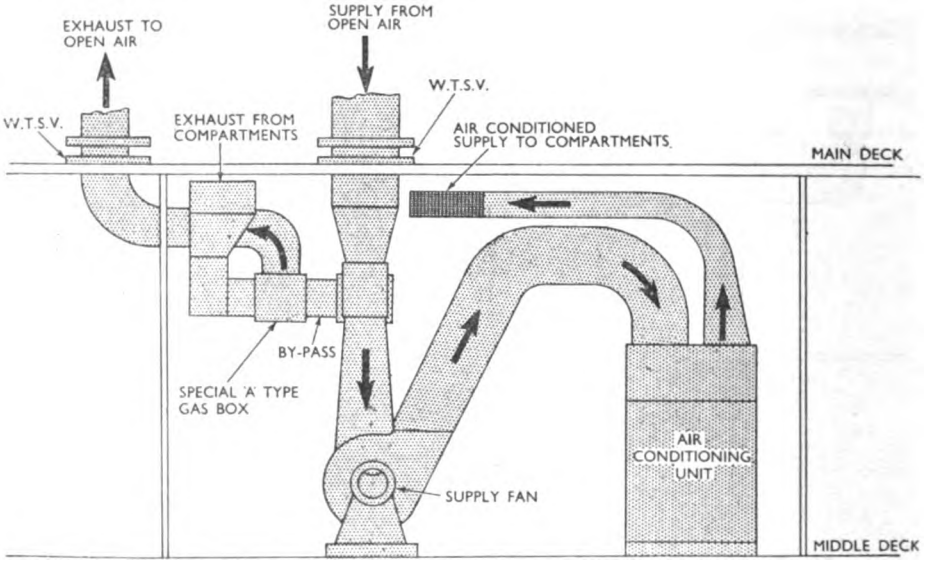

Fig. 111. Typical air-conditioned ventilating system between decks

The air-conditioning plant consists of an air cooler which is provided with a sufficient supply of fresh air to keep the atmosphere in the compartment pure. The cooled air, which is dried in the process of cooling, is circulated at a low pressure round the compartment. A small exhaust is provided to maintain normal pressure within the compartment and to free the air of any impurities.

Fans

The following types of fan are provided in H.M. ships :—

(i) *Centrifugal Fans.*—The normal ventilation fans are of the centrifugal type and must be capable of propelling air against a medium or high resistance. When working normally they have the following outputs :—

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Nominal Size of Fan (in.)	*Output cu. ft./min.*
5	500
7½	750
10	1,300
12½	2,000
17½	4,000

The size quoted for a fan refers to the diameter of its rotor.

(ii) *Axial Flow Fans.*—These are used to propel large volumes of air against a low resistance, and they have the advantage that they can be incorporated in the trunking system with a consequent saving of space. At present (1953) their use is limited to the ventilation of spaces such as engine-rooms, auxiliary machinery spaces and hangars. Their normal output is given below.

Nominal Size of Fan (in.)	*Output cu. ft./min.*
12½	2,200
17½	5,000
20	7,500
25	12,000
30	17,500
35	23,500

(iii) *Ceiling and Table Fans.*—If there is sufficient headroom ceiling fans of the propeller type are fitted to the deckheads of compartments such as wardrooms, sick-bays and cinemas. Table fans are provided for cabins and offices. The function of both is to increase air movement, they do not supply fresh air.

Fans can be run at full speed continuously in the tropics because their motors are designed for this purpose. Fans above 17½-in. in diameter are usually provided with three speeds; two speeds are provided for 17½-in., 12½-in. and 10-in. fans; 7½-in. and 5-in. fans can be run at one speed only.

Air Supply Terminals

These consist of punkah-louvres, distributors, and bellmouths.

The punkah-louvre directs a stream of air from the supply trunk in any direction within a cone the angle of whose apex is about 85°, and it has an effective range at normal working pressures of from about 6 to 12 feet, depending on its size. This air stream is of considerable advantage in hot climates. Under cooler conditions the air velocity can be reduced by running the fans at a slower speed, and the punkah-louvres can be adjusted to direct the air flow away from the occupants of the compartment. In cold climates air-diffusers may be fitted to the punkah-louvres, and some of the punkah-louvres may be shut off. In living and messing spaces fitted with heaters, relief valves are fitted on the ventilation trunking and these come into operation as the punkah-louvres in the system are shut off.

Distributors are usually employed in air conditioned compartments to ensure that the cold air coming in is mixed with the air in the compartment.

Bellmouths, for delivering large volumes of air, are used only in hot compartments, and should not be used in the same system as punkah-louvres or distributors.

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Arrangements for Preserving Watertight Integrity

Main transverse and longitudinal watertight bulkheads are not penetrated below the datum deck by ventilation trunking. Watertight trunking in modern ships is provided wherever the trunks are a potential source of further flooding, and they are fitted as necessary with watertight sluice-valves. Suitable positions for operating the valves are chosen to facilitate the control of flooding or fire in the event of damage.

Supply inlets and exhaust outlets are fitted above the weather decks, in positions least likely to be affected by seas and spray. The exhaust outlets are usually higher than the supply inlets and they are kept as far from them as possible so that the foul air from the exhaust will not be drawn back into the ship and re-circulated. Inlets and exhausts are usually fitted with water-excluding heads of the " French " type, or with hinged watertight covers.

Gas Citadel

The central and vital part of the ship is known as the " gas citadel," and to prevent gas from getting into it gas-flaps are fitted under the weather deck openings of its ventilation trunks. The three different types of gas-flap are described below.

(i) *The " A " type*, which is a combined watertight and gastight flap and is used in supply systems. The flaps can be set so that the air supply is drawn either from the open air, or from an adjacent compartment for re-circulation ; during a gas attack the flaps are set so that the air already in their sections of the ship is re-circulated.

(ii) *The " B " type*, which is a combined watertight and gastight flap which can be completely opened or completely shut. It is generally fitted in exhaust systems to prevent gas from leaking into the exhaust trunks.

(iii) *The " change over " type*, which is used in conjunction with a filtration unit ; it enables the air supply to be drawn directly from the fresh air via the filtration unit during a gas attack.

Organisation of Ventilation

The control of ventilation in a ship, especially when in the tropics, requires an efficient organisation to ensure, on the one hand that there is adequate ventilation for the ship's company, and on the other that the watertight integrity of the ship is maintained. The ventilation and integrity patrols require a training which aims at giving each man an intimate knowledge of the section of the ship in which he works. Positions of fans and starters in relation to the compartments which they serve must be memorised, and ventilation routines should be prepared to meet the requirements of the different climates met with and the different tactical conditions under which the ship may be employed, the importance of maintaining watertight integrity being always taken into account.

Immediately the ventilation supplies on the weather decks are shut down, heat and humidity within the ship increase appreciably, so it is important that they should be left open for as long as possible when the higher degrees of readiness, or states of damage control are about to be assumed. If a compartment is closed down, the supply of air is seriously reduced unless an efficient

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exhaust is provided; it is therefore as important to ensure that the exhaust is open as to ensure that the supply is working.

When lying in harbour during hot weather in the tropics considerable relief from the heat can be obtained by periodically using the powerful engine-room exhaust fans for changing the air in the mess decks and flats, doors and hatches being adjusted as necessary.

There is a tendency on the part of men, particularly those who sling their hammocks close to supply trunking, to shut off punkah-louvres, and this practice should be discouraged. Instead, the louvre should be directed in such a way that no annoyance is caused, but its maximum flow must be maintained in order to maintain the required rate of change of air in the compartment. The practice of fitting cloth filters to punkah-louvres should also be discouraged because the filters greatly impair the air flow, especially when they become clogged with dirt, and so cause unduly high internal temperatures and humidities.

Punkah-louvres operate correctly only within certain definite limits of air pressure in the trunking, and fitting additional " home made " supply terminals may therefore react seriously on the whole system. For the same reason the fitting of " home made " deflector plates to supply openings should be discouraged.

Ventilation systems must be inspected and thoroughly cleaned out at regular intervals, say once every three months, otherwise their performance and efficiency deteriorate considerably. Inspection plates and drain plugs are provided where necessary and they should always be removed at the periodical inspections. Routine cleaning is best effected by blowing through the whole system, section by section, with the ship's compressed air service.

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CHAPTER XVI

Equipment and Maintenance of Warships

EQUIPMENT AND STORES

THERE IS NO well-defined dividing line between the terms "equipment" and "stores" when used to describe all the equipment, fittings, and other gear carried in a ship. Broadly speaking, however, equipment may be said to comprise the fittings or gear which are regarded as being an integral part of a ship, made expressly for her, or fixed more or less permanently in place, while stores consist mainly of things of a standard nature which are supplied for the general running and maintenance of ships throughout the Fleet.

The nature and amount of the equipment and stores carried in a ship are based largely on experience gained from previous ships of similar design.

Equipment

The equipment of a ship is classified generally under the headings "ship's fittings" and "portable fittings."

Ship's fittings comprise items which are built into the ship or are integral parts of her, examples being: the armament; pumps, fans and other auxiliary machinery; masts and yards; propellers and rudder; capstans, winches and bollards; and boat booms.

No accounts are kept for such equipment, and it is not taken on charge by the ship's officers.

Portable fittings are either portable or can readily be made so, and they are divided into the four following categories:—

(i) Fittings which are made for a particular ship and which, therefore, are not interchangeable with other ships, examples being: ship's badges, running rigging, davits, awnings and other canvas gear, slings and fitted furniture not classed as "naval stores" (*i.e.*, stores listed in the *Rate Book of Naval Stores*).

(ii) Fittings which may be interchangeable with other ships, but which though of a standard nature are not classed as "naval stores," examples being: kit, flag, cushion, and bread lockers; davits; rifle racks; and ventilators.

(iii) Spare parts of machinery, including small spares, which have not been standardised as "naval store" articles. These are usually known by the term "spare gear."

(iv) Certain fittings which are classed as "naval stores" and which, though fitted in place, can be made portable. There are few such fittings, the chief ones being switches and other standard electrical fittings.

All these items must be accounted for and taken on charge by those ship's officers who are chiefly concerned with their use and maintenance. Lists of portable fittings and spare gear are therefore prepared by the main contractors in conjunction with Admiralty Overseers or Dockyard Officers, and Ship's Officers, under the six following headings:— Boatswain, Gunner (G), Gunner

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(T.A/S), Engineer, Shipwright, and Electrical Officer. Each comprises a list of the fittings and gear with which that officer is charged, a memorandum of instructions, an index and a list of drawings, all bound together in a cover.

Three copies of each list are prepared, and after each has been signed by the officers concerned two copies are retained in the ship and one is returned to the Dockyard for retention by the professional officer concerned.

Stores

Stores are classified under these five main headings: "naval stores," "armament and torpedo/anti-submarine stores," "victualling stores," "stationery, books, and forms," and "canteen stores." Separate regulations govern the issue, provision, accounting, maintenance, and return of each main class of stores.

Naval Stores

The term "naval stores" includes all standard items of an established pattern which are in general use for the work or upkeep of a ship. They are catalogued in *B.R.* 810—*Rate Book of Naval Stores,* which is an authorised list and a priced index of naval stores, and the regulations governing their supply are to be found in *B.R.* 4—*Naval. Storekeeping Manual.*

For cataloguing, accounting and indexing purposes naval stores are classified in the *Rate Book* under the following eight main classes, each class except A, C, EE and K being sub-divided into a number of "groups."

CLASS	DESCRIPTION OF STORES
A	Timber and timber materials.
B	Metals and metal articles.
C	Coal, coke, etc., for Yard purposes.
D	Textiles, such as canvas, flags and cordage.
E	Miscellaneous articles, such as rubber, furniture, and paint.
EE	M/T vehicles and their accessories, and bicycles.
F	Electrical stores, including W/T, asdic, and radar equipment.
K	Oil fuel, and coal for Fleet services.

Each item of naval stores is normally given a specified pattern number to enable it to be positively identified, and when such stores are demanded, returned, or otherwise referred to, the correct class, group, pattern number and description, as shown in the *Rate Book,* should always be quoted. Exceptions to this rule are certain items of which the description, size or other distinguishing feature is sufficiently explicit to identify it, examples being timber, steel structural materials, and anchors and chain cable.

Naval stores are generally also classified under the two following categories:—

(i) *permanent stores* which have a reasonably long life, are not consumed or destroyed in normal use, and are sufficiently valuable to be completely accounted for; and

(ii) *consumable stores* which are consumed or destroyed in use within a limited period, or are of such low value that they need not be completely accounted for.

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Sea Stores.—Naval stores issued to ships are known generally as "sea stores," and their quantity and type for each type and class of ship are detailed in books of reference called *Establishments of Sea Stores. B.R.* 358, for example, is the *Establishment of Sea Stores for Executive Purposes for Capital Ships, Cruisers, Aircraft Carriers, Depot Ships and Repair Ships.*

From such establishments an officer can ascertain the standard, or "fixed," allowance of stores for his particular ship. Individual ships, however, sometimes require quantities or types of certain stores which differ from the fixed allowance owing to some peculiarity in their design or equipment, or to some difference in the nature of the duties they are required to perform. This is allowed for by what is known as a "scale allowance," details of which are shown in a supplementary list called the "Ship's List of Particulars." This list is prepared in the first instance by the ship's officers appointed to stand by her while she is being built, and subsequently it may be altered in accordance with experience gained when the ship is in commission.

Sea stores shown in the executive establishments are classified as "first fitting stores" (FF), "fitted stores" (F), "navigational stores" (N), and "other stores."

First fitting stores comprise: the anchors and cables, together with their associated gear; boats, life-rafts and life-floats. These are usually sent to the ship when she is in an advanced stage of construction.

The repair or replacement of such stores constitutes a defect which should be recorded in the "Pink Defect List."

Fitted stores are those which, though fitted in certain positions in the ship, are *readily* portable, fire appliances for example, and they should not be confused with the "portable fittings" already described. Fitted stores are usually sent to the ship and fitted in place while she is being built.

Navigational stores are those which are necessary to enable the ship to put to sea before being commissioned, either for trials or for passage from her fitting-out port to the storing yard.

Other stores shown in the establishment which have no particular designation comprise all the sea stores necessary for the running and maintenance of the ship while she is in commission.

Accounting Procedure.—Full particulars of all permanent and consumable sea stores issued to a ship are entered by the Superintending Naval Store Officer of the storing yard concerned in two types of loose-leaf ledger, one for permanent stores and the other for consumable stores. These ledgers are then handed to the ship's Supply Officer as a record of all the stores on his charge. Subsequently, those permanent sea stores which are not stowed in store-rooms are taken on charge by the various departmental officers of the ship chiefly concerned with their use and maintenance, and for this purpose the ship's Supply Officer prepares and issues lists of such stores, known as "Permanent Loan Lists," to the heads of the various departments.

Issue of Consumable Stores.—Consumable stores used to be issued by quantity in accordance with scales specified for each class of ship. This rigid system was unsatisfactory because it did not allow for the widely varying conditions under which ships serve, and so it was superseded by what is known as the "valuation allowance system." Under this latter system each head of a

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department is allowed a specified quarterly monetary allowance for the maintenance and cleanliness of his department. It is a flexible system which allows considerable latitude in the choice and quantity of stores necessary to maintain a proper standard of smartness and efficiency throughout the ship.

The quarterly monetary allowances for each department in each class of ship are given in Appendix I to the *Naval Storekeeping Manual.* Every month the Supply Officer of the ship provides each head of a department with details of the value of consumable stores issued to his department during the previous month. These valuation allowances are not intended to cover the expenditure of stores on repair work or refitting, for which special allowances of stores are made.

Stock-taking and Musters.—Stock-taking in a ship is usually a continuous procedure, organised so that all the sea stores carried are mustered at least once every eighteen months. Stores on permanent loan lists, and any valuable or attractive articles, such as binoculars and stop-watches, should be mustered at six-monthly intervals.

Storing Battleships, Carriers and Large Cruisers.—These ships are stored initially for a period of six months, the interval between successive re-storings is usually four months, and the minimum stock which should be maintained is usually equivalent to two months' issue at the normal rate of expenditure. The corresponding periods for smaller ships vary from one to four months, according to the size of the ship.

Armament and Torpedo Stores

The descriptions and quantities of armament and torpedo/anti-submarine stores allowed to different types and classes of ships are given in the *Proportion Book of Naval Armament Stores,* which is somewhat similar to the establishment books for sea stores.

Armament Stores.—This term includes: portable weapons and spares for the fixed armament of the ship, *e.g.*, gun barrels and breech blocks; small arms, *e.g.*, rifles, revolvers, and associated equipment; and all ammunition and other explosives such as pyrotechnics.

Types and quantities of armament stores comprising a ship's outfit are listed in the "Gunner's Warrant." Their issue, stowage, maintenance, and return are governed by the *Naval Magazine and Explosives Regulations* and the *Naval Cordite Regulations.* They are accounted for by the ship's Gunnery Officer, in the Naval Armament Stores Ledger.

Ammunition and explosives not required for immediate use are stowed in the magazines and shell rooms. Small arms, portable weapons, and spares for the fixed armament are stowed in fixed stowages around the ship. Other items are usually stowed in the Gunner's Store. Special precautions are taken to ensure the safe custody of small arms and portable weapons.

Representative samples of ammunition and other explosives are landed for examination and proof as required by the regulations, and the complete ship's outfit of ammunition and explosives is landed periodically at a Naval Armament Depot for examination.

Torpedo/Anti-Submarine (T.A/S) Stores.—This term includes all underwater weapons and equipment for defence against underwater attack, *e.g.*,

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torpedoes, depth charges, mines, paravanes, mine-sweeping gear, and protective nets.

Types and quantities of T.A/S stores comprising a ship's outfit are listed in the " Torpedo Gunner's Warrant," and accounted for by the ship's T.A/S Officer in the Torpedo Stores Ledger.

Torpedo warheads are usually stowed in the " warhead room " ; depth charges are stowed in racks round the weather decks, and any not required for immediate use may be stowed in the warhead room ; mines are stowed on the mining deck of minelayers. Other T.A/S equipment is stowed either in fixed stowages around the ship or in the T.A/S Gunner's Store.

Victualling Stores

The term " victualling stores " covers a wide variety of articles, many of which are not usually associated with the word " victuals " as applied in its normal sense to mean food and drink. The different victualling stores for H.M. ships are listed below.

Provisions, which are sub-divided into " fresh provisions," *e.g.*, fresh fruit, fresh vegetables, and fresh and frozen meat, and " dry provisions " which comprise all other foodstuffs, including rum and vinegar.

Clothing, which includes articles of kit such as hammocks, kit-bags, attaché cases, suitcases, beds and bedding. It is classed generally as " free-issue clothing," " cash clothing," *i.e.*, supplied on repayment and commonly called " slops," and " loan clothing."

Soap and tobacco, which are provided from Service sources.

Mess gear, which comprises everything used for preparing, serving and eating of food. These are of three kinds, classified as follows :—

Officers' Mess Traps ... ... for officers' messes and pantries ;
Mess Utensils ... ... for ratings' messes ;
Implements and Galley Gear... for all galleys.

Medical comforts, which include special articles of food and drink as prescribed by the Medical Officer for the sick ; examples being pearl barley, soups and broths.

Libraries, containing reference books, educational books, and fiction.

Scales and Quantities.—The scale of victualling stores for any particular ship depends mainly on her complement and on the station to which she is allocated. In the first instance the Supply Officer of the ship is responsible for estimating the quantities of each item he will require, and then demanding them from the Victualling Yard concerned. The quantity of provisions to be carried is based on the capacity of the ship's provision store-rooms and on her complement, and the quantities of other stores are based on the scales laid down in the appendices to *B.R.* 93, *Victualling Manual*, which also gives instructions for the issue, inspection, stowage, maintenance, and return of all victualling stores.

Stocks.—In sea-going ships stocks of fresh provisions are regulated according to the ship's requirements and to her facilities for keeping fresh provisions in good condition. Instructions regarding the maximum and minimum quantities of dry provisions to be maintained in different classes of ships are published from time to time in *Admiralty Fleet Orders*.

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A reserve stock of mess gear is held on board and is limited to one year's estimated expenditure, but it should not exceed the value of the annual monetary allowance for the replacement of worn or broken items.

Under normal conditions of service the stock of clothing held should not exceed three months' average requirements.

Stock-taking and Musters.—In a sea-going ship the intervals between stock-taking and musters of victualling stores, both in store and issued on loan, vary according to the type of store and the type of ship. Stock-taking and musters are intended to check the quantities and the condition of each item remaining in store, and those issued on loan, and to check the records of their expenditure.

The following table shows how often and by whom each type of victualling store has to be mustered or checked for stock-taking.

KIND OF STORE	FREQUENCY OF MUSTERING AND OFFICER RESPONSIBLE
Medical Comforts	... every six months—by the Medical Officer and the Supply Officer.
Provisions	... monthly in destroyers and smaller ships—by the Captain's deputy; quarterly in other ships—by the Supply Officer. On foreign stations the interval may be extended up to six months at the discretion of the Commander-in-Chief.
Libraries and Books of Reference	... quarterly—by the Supply Officer or the Captain's deputy.
Clothing, Soap and Tobacco ...	... monthly for items issued on repayment, and quarterly for others—by the Supply Officer or the Captain's deputy.
Officers' Mess Traps	
In ships without a Supply Officer	... every six months—by the Supply Officer of the parent ship or the base.
In ships with a Supply Officer	... every six months—by an officer.
Mess Utensils...	... at least once a quarter—by the Divisional Officer concerned, assisted by a representative of the Supply Officer.
Implements and Galley Gear...	... quarterly—by an officer.

STATIONERY, BOOKS AND FORMS

In addition to stationery, such as paper, pens, pencils, ink and notebooks, this term includes stationery for school use, files and filing cabinets, typewriters, and office machinery such as duplicators, calculating machines, photo-copying apparatus, and printing presses; but it does not include "Admiralty Established Forms" and "Books of Reference" (B.R.s).

Stationery which could be classed as permanent stores, such as typewriters, filing cabinets and office machinery, is taken on charge by the ship's Supply

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Officer, entered in the ledger in the same manner as permanent naval stores, and then issued to individual officers on permanent loan.

The scales of stationery for H.M. ships are based on the number of persons doing clerical work, the type of ship and the duties on which she is engaged. Details of these scales, and leaflets giving particulars of " commissioning sets " for various classes of ship, can be obtained from the Keeper of Stationery and Printing, Admiralty, London, S.W.1. The establishment of typewriters and duplicators for all classes of ships is published in *Admiralty Fleet Orders*. In the first instance sea-going ships are issued with a commissioning set of office stationery sufficient for six months. Thereafter demands for the replenishment of stationery stocks should be forwarded on *Form S.*1310 to the Keeper of Stationery and Printing at intervals of six months.

The list and scales of allowances of Books of Reference (B.R.s) for H.M. ships is given in the catalogue *B.R.*1., which also gives detailed instructions regarding their issue, custody and return. On commissioning, ships are supplied, without demand, with a complete set of the B.R.s to which they are entitled, by the R.N. Store Depot at Park Royal, London.

Lists, allowances and full instructions regarding the issue, custody and return of Confidential Books (C.B.s) are given in *Forms U2A* and *U2D*. On commissioning, a ship is issued with a complete set of the C.B.s to which she is entitled, by the Commander-in-Chief or other administrative authority of the port where she commissions.

Lists and allowances of Established Forms (*i.e.*, printed forms for issue to H.M. ships and commonly called " S Forms ") are given in *Forms S–*1 and *S–*1*a*. On commissioning, ships are supplied, without demand, with a complete set of forms sufficient to last the whole commission. Instructions regarding the issue, demand and transfer of S Forms are given in *Form* S–1.

Canteen Stores

These are the property of the Navy, Army and Air Force Institute, and their provision, custody and accounting are the responsibilities of the ship's Canteen Manager and officials of the Institute. They are stowed apart from Government stores in the ship's canteen and in store-rooms specially allocated to them. Ship's officers have no responsibilities in regard to canteen stores except those of providing reasonable facilities for their issue, care and custody. Apart from the sale of canteen stores to individuals and to messes, they may be purchased by the Ship's Supply Officer to supplement the government ration of food.

MAINTENANCE AND REFITTING

Defects

Damage to the structure, fittings and equipment of a warship caused by accident or by wear and tear becomes, for purposes of classification for repair or replacement, what is known officially as a " defect " ; this does not apply, however, to naval stores, except " first fitting stores."

Any defect, however small, must be reported as soon as it is discovered, and full details of it must be recorded. For this purpose each department of a ship keeps a *Departmental Rough Defect Book* (*S.*342). Departmental defect lists are divided into the two following categories :—

(i) defects which can be remedied by the ship's artificers, known generally as the " ship's staff " ; and

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(ii) defects for which dockyard assistance is essential.

The first category is sub-divided into those items which can be remedied while the ship is in service, and those which must wait until the ship is at a dockyard port for boiler cleaning, docking or refit.

Defects which require dockyard assistance, and those which cannot be undertaken by the ship's staff while the ship is in service, are recorded in the *Ship's Record of Defects* (*S.*342), which is inspected and checked once a week by her Commanding Officer. This record is a very valuable guide to the captain of a ship, because it enables him to tell at a glance to what extent the seaworthiness or operational efficiency of his ship may be impaired. From this record are compiled the " main " and " supplementary " defect lists of the ship which are forwarded to the dockyard authorities before the ship is taken in hand for a refit.

Defect Lists.—Before a ship is due to be taken in hand for a refit all outstanding defects are listed on special forms (*S.*340—" pink," and *S.*340, B—" white "). These lists are forwarded to the dockyard concerned well before the ship's arrival for refit to enable the materials and labour necessary for the repairs to be arranged.

Defects are listed on these forms in the following categories :—

(i) repairs essential for the fighting and sea-going efficiency of the ship ;

(ii) repairs essential for any other reason ;

(iii) repairs which will be undertaken by the ship's staff, with or without dockyard assistance, during the refit.

These categories are briefly described below.

(i) Repairs essential for the fighting and sea-going efficiency of the ship are the most important, and they are listed on *Form S.*340, which is printed on pink paper, and the list is therefore commonly called the " Pink Defect List." Also included in this list are repairs to, or replacements for, first fitting sea stores, and requirements for surveys, routine examinations and tests by the dockyard.

(ii) Repairs essential for other reasons comprise all the other defects which require to be made good by the dockyard. These are listed on *Form S.*340, *B*, which is printed on white paper and commonly called the " White Defect List." Also included in this list are demands for spare gear, portable fittings and similar equipment.

(iii) Work to be undertaken by the ship's staff includes making good defects which are within the capabilities of the ship's artificers if they are given dockyard assistance. Such work is recorded in the " Pink " and " White " defect lists as appropriate, and further categorised as :—

work for which finished materials are to be supplied by the dockyard ; and

work for which unfinished materials are to be supplied by the dockyard.

Such work, together with any work which cannot be classified as repairs to essential defects, is also listed on a form *S.*340, *D*, which is compiled principally for the information of the ship's administrative authority and of the dockyard officers to show that the ship's staff will be fully and usefully employed during the refit period.

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After defects have been listed as " Pink," " White," and " Ship's Staff " they are sub-divided under the following headings :— " Hull and Miscellaneous Fittings " ; " Engines " ; " Boilers " ; " Auxiliary Machinery " ; " Weapons (general and electrical) " ; " Main Electrical " ; " First Fitting Stores, Portable Fittings, and Spare Gear."

Usually two hectograph and up to eight carbon copies of the defect lists are made. These are forwarded at least six weeks before the ship is due to refit to her administrative authority who, after scrutinising them carefully, sends them on to the mechanical training establishment of the port concerned, or for a small ship to her Depot Ship, where those items which can be undertaken by the Depot Ship or M.T. establishment are indicated on the lists. The lists are next sent to the Superintendent of the Dockyard concerned so as to reach him at least one month before the ship is due to refit. At the dockyard as many as 45 or more copies of the defect lists may be made and distributed to its various departments. The dockyard officers of each department then investigate those items that concern them and state whether the work can be undertaken and the length of time required. An estimate of the total cost involved is then forwarded to the Superintendent of the Dockyard for his approval to put the work in hand.

Any unforeseeable defects discovered after the main defect lists have been forwarded are reported on " Supplementary Defect Lists." These are compiled in a similar manner to the main defect lists but marked " Supplementary Lists," and they are then sent direct to the Superintendent of the Dockyard (copies being sent to the ship's administrative authority) ; they must be accompanied by a statement by the ship's Commanding Officer giving reasons why these items were not included in the main defect lists.

From the procedure just described it will be seen that an inaccurate or incorrectly compiled defect list may cause much unnecessary work and waste of time ; great care should therefore be taken to ensure that the defects are correctly described in full detail, and that the rules which accompany the forms are closely followed.

Alterations and Additions

The term " alterations and additions," commonly called " A's and A's," is used to describe improvements to the structure, machinery, armament or equipment of a ship to enhance her seaworthiness, fighting efficiency or habitability. Proposals for A's and A's may be initiated in the Fleet or by Admiralty departments, and if approved by the Admiralty each is classed A, B or C according to which of the three following categories it belongs :—

A ... items essential for the sea-going or fighting efficiency of the ship, or for her habitability ;

B ... items which cannot be classed as A but which are approved for incorporation in existing ships when the opportunity occurs ;

C ... items which, though not meriting the cost of carrying them out in existing ships, should be incorporated in future design.

In cruisers and larger ships, and in surveying vessels, the Captain is responsible for co-ordinating the various A's and A's approved for his ship and for forwarding the necessary returns to his administrative authority. In destroyers and smaller vessels a co-ordinating authority, such as the flotilla commander,

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is detailed by the Admiralty. Items in category A are recorded by the co-ordinator on a *Form S.*1182, and those in category B on a separate list, and both are forwarded by the co-ordinator through his administrative authority to the Admiralty on completion of building or refit, and also nine months before the start of any reconstruction or a large repair.

Details of all A's and A's, whether only proposed or approved, are recorded on *Form S.*345, *Record of Alterations and Additions*, which is kept in all ships, and from this record the lists of A's and A's for categories A and B are prepared.

Particulars of A's and A's which have been approved in principle by the Admiralty together with the names or classes of ships affected, are published from time to time in *Admiralty Fleet Orders ;* those in category A may be carried out during a periodical refit, but those in category B are usually effected only when a ship is undergoing reconstruction or a large repair. A's and A's which can be done by the ship's staff, however, may be taken in hand as soon as an opportunity occurs.

Admiralty approval of an A and A does not necessarily mean that it will be carried out at the first opportunity, or even during a periodical refit, because this depends largely on whether the necessary labour and materials are available. Any which are essential for the safety of the ship, however, are taken in hand at the first opportunity.

Maintenance

In addition to the normal routine maintenance necessary to keep a ship clean and habitable, and her equipment in good working order, the ship's staff are required to carry out such examinations, running repairs and replacements as are within their capabilities and resources. Each ship is therefore provided with machines, tools and stores, the types and quantities of which depend upon the class and number of artificers and artisan ratings she carries.

To enable the full repair resources of a ship to be used to the best advantage, each departmental officer (*e.g.*, Gunnery Officer, T.A/S Officer, Navigating Officer, Engineer Officer, Electrical Officer, Boatswain, and Shipwright Officer) renders a weekly return to the Captain showing the defects outstanding in his department, the repair work carried out during the week, and the work he proposes to have done during the coming week. These reports show the Captain, at a glance, the progress made in remedying defects, and whether any particular measures are necessary to assist or expedite the repair of a particular defect.

Many Captains hold a weekly conference with their Executive Officer and Heads of Departments at which the future programme of the ship is discussed ; this enables full advantage to be taken of any period when the ship is out of routine or steam is down, when major defects can be dealt with and any examinations or surveys be carried out. If making good a defect ordinarily classed as " repairable by ship's staff " is beyond the resources of any particular ship, her Captain informs his Senior Officer, and the latter may then arrange for the extra artificers or materials required to be provided by his fleet, squadron, or flotilla.

This organisation not only ensures that a ship is always maintained in as efficient a condition as possible, but it also ensures that when she is next taken in hand for docking or refit the number of her defects is reduced to those for

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which dockyard assistance is essential, and thus reduces to a minimum the period required for the refit.

Ship's Staff Work

Work of the following nature is usually carried out by ships' staffs :—

Carrying out minor repairs to boats, booms, guard rails and stanchions, ladders, racks, lockers, mess shelves, tables and stools, skylights, ports, cupboards, locks, tallies, the heads, pumps, fresh and salt water services ; effecting small repairs to the ship's galley, valves and gearing, and to electric light, power and communication circuits and fittings.

Repairing and renewing of corticene. Renewing rubber joints on watertight doors, hatches, scuttles and manhole covers.

Caulking and repairing wooden decks if the work is not extensive, and letting down the fastening of decks.

Fitting wire ridge-ropes.

Surveying hull structure and fittings and air-testing compartments.

Painting generally and also polishing woodwork, and maintaining cabin fittings for which tools and materials are allowed and carried. (The painting and renovation of furniture in Flag Officers' and Captains' apartments, officers' messes and the Sick Bay is, however, done by dockyard labour.)

Repairing canvas and rigging.

Examining and refitting underwater fittings.

Surveys and Tests

The discovery and reporting of defects in their early stages, when they can most easily be made good, is very important. With this object the ship's staff carry out a continuous survey of the ship while she is in commission. Such a survey includes a thorough and methodical examination of every compartment to ensure that it is watertight, free from corrosion and defects, and kept clean and painted, and the survey should be so arranged that each compartment is examined once in six months in destroyers and smaller ships, and once a year in larger ships. In addition to this survey, each compartment is air-tested for watertightness, and minor repairs to the structure and fittings are carried out as defects are revealed. In addition to this survey of the ship's internal structure her underwater fittings should be examined, and repaired if necessary, whenever the ship is dry-docked. All equipment and fittings should also be surveyed so that each is thoroughly examined at least once a year.

Routine Inspections and Surveys of the Hull and Hull Fittings.—Watertight doors, hatches and valves on which the safety of the ship depends should be inspected once a week, and a routine should be prepared for inspecting other important fittings, particularly those which are little used and places difficult of access, at frequent and regular intervals. Examples of such places and fittings are : the inner-bottom plating under machinery and boilers ; the bottoms of transverse and longitudinal bulkheads ; compartments containing oil and water, or in which water is liable to accumulate ; any place where there is a hot, damp atmosphere ; sea-cocks and flooding valves ; and pipes for de-icing underwater valves.

The survey of the internal structure and compartments should be methodically carried out, and for this purpose the ship should be divided into sections, and the inspection be organised so that each compartment in each section is

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inspected within the prescribed period. When a compartment is inspected all watertight doors, hatches, scuttles, manhole covers, pipes, ventilation valves and gearing should also be inspected, and refitted or repaired as necessary. At the same time the compartment should be subjected to an air test unless it is one which normally contains liquid in bulk, or is situated amidships and above the deep-load waterline, or is situated at the ends of the ship with one clear deck-space between its deck and the deep-load waterline.

Care must be taken when entering compartments which have been little used and which may lack oxygen or contain toxic or combustible gases. The precautions necessary are laid down in the various books of regulations, such as the *Engineering Manual, Queen's Regulations and Admiralty Instructions*, and the *Home Dockyard Regulations ;* the procedure is also described in Chapter II of Volume II of this manual.

Drinking water tanks which are internally coated with a cement wash or a bituminous composition should be inspected frequently and cleaned out at regular intervals. The regulations lay down that only naval ratings who have been examined by the medical officer should be employed to clean drinking water tanks, and that their clothing and shoes are to be disinfected before cleaning is begun. Oil tanks containing heavy, filtered mineral oil should also be inspected frequently.

Reports of all surveys carried out by the ship's staff are rendered to the ship's administrative authority and the Admiralty on *Form S.*180, and a copy is kept in the *Ship's Book.*

Whenever the ship is docked the general condition of the outer-bottom compositions, the outer bottom, and fittings such as the rudder, rope-guards, eddy-plates, propellers and their exposed shafting should be noted. All zinc protectors should be carefully examined to ensure that they are properly secured with a good metal-to-metal contact with the steel, and that they are clean and bright and not unduly corroded.

Surveying and Testing Equipment.—All equipment and first fitting stores are surveyed and tested at regular intervals, as laid down in various books of regulations, such as *Queen's Regulations and Admiralty Instructions*, and *B.R.*367, *Anchors, Chain Cables, etc.*, and also in *Admiralty Fleet Orders*. The reports of all surveys of equipment are rendered on *Form S.*331, and those of anchors and chain cables on *Form S.*194. The results of all tests of equipment are recorded in the *Ship's Book.*

Some surveys and tests are carried out by the ship's staff and others by dockyard departments. The table on pages 378 and 379 shows the periodical examinations, surveys and tests of upper-deck gear, and of lifting appliances, for sea-going ships. Defects in equipment and first fitting stores are entered in the defect lists together with demands for any replacements.

In addition to the periodical tests required by regulations, any equipment is tested after it has been repaired or if its rig has been modified in a manner likely to affect the strength of any component part.

A lifting or handling appliance is designed to function when rigged in a certain way, and it should not be tested when rigged in any other way. Each lifting or handling system is tested as a complete unit, and the nature of the tests to be applied are detailed in the ship's drawings and also in the *Ship's Book*, in which are recorded the results of all previous tests. Whenever any

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unit or system has been tested the relevant particulars of the test, such as the static, running, or safe working loads, are stamped on the unit or marked on a tally-plate fixed to the system.

NOTES ON MAINTENANCE

Corrosion.—The three chief sources of corrosion are:—

(i) *Rust (or oxidisation).*—This occurs when bare steel or iron is exposed to water or the weather ; it is caused by the slow chemical combination of iron with the oxygen in the atmosphere.

Rusting is accelerated by heat, and once started it extends rapidly. Rust also forms a medium for galvanic action, because it is electro-negative to iron and steel.

The best way to keep bare iron or steel from rusting is to keep it clean and covered with a light film of suitable oil or grease ; painted iron or steel must be kept effectively coated with paint.

(ii) *Galvanic Action.*—Sea water has a weak acid reaction, and galvanic action therefore occurs if certain different metals make contact with each other when immersed in sea water. Galvanic action can also be set up between two parts of the same plate if they have been treated differently, or if they are covered with mill-scale ; plates are therefore " pickled " before use to remove any mill-scale on them.

Rusting of a surface will be fairly uniform, but corrosion caused by galvanic action is irregular and will often form patches of pitting in a steel surface.

No copper-bottomed vessel should be allowed to lie alongside a steel-built vessel, or be secured to the same, or adjacent, moorings, otherwise their hulls will be subjected to galvanic action. Galvanised steel and copper-nickel-iron alloys are not subject to galvanic action ; the latter are therefore used as much as possible for salt-water pipes, and the former for fittings which are in contact with sea water or exposed to the weather. The hulls of certain ships are also built of galvanised plating.

Corrosion pieces, or protectors, of zinc are fitted to the hull wherever copper or bronze is in contact with or near the steel structure, *e.g.*, near the propellers, rudder-head and fore side of the rudder, in the main inlets and discharges, and at the sea-cocks. Zinc being electro-negative to copper or copper alloys these corrosion pieces or protectors absorb any galvanic action, and in course of time they are eaten away by it. The protectors therefore need inspecting, and renewing if necessary, each time a ship is docked. Zinc protectors must not be painted because this destroys their function.

Aluminium alloys are now being used for the superstructures of certain ships because of their freedom from corrosion ; care must be taken, however, to ensure they are not in contact with steel, bronze or copper. The best priming paints for aluminium alloys are zinc-chromate-red, and aluminium paints.

(iii) *Sweating.*—This is caused by condensation of moist air on a cold internal surface. The moisture produced by sweating runs down the sides of a compartment and collects in inaccessible places where it eventually

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seeps through the paintwork and so causes rusting. It also makes the atmosphere of the compartment damp and so accelerates the deterioration of the paintwork.

To reduce sweating, the deckheads, and sometimes the sides of a compartment, are covered with "sprayed limpet asbestos lagging" or granulated cork. These compositions absorb moisture, and sprayed limpet asbestos also serves as an insulator. Surfaces covered with these compositions should be painted only with the approved grades of water-paint, distempers, or other approved coatings; these are porous and so allow the moisture to penetrate to the composition or cork.

Ventilation Systems.—The ventilation systems of a ship require constant and careful maintenance, not only to ensure that they function correctly but to maintain her watertight integrity.

Trunking should be examined at least once a month and cleaned out as required, and if possible it should be blown through by compressed-air blast once a quarter. In ships not provided with a low-pressure air system, advantage should be taken of the shore low-pressure air system when lying alongside in a dockyard port. The air blast should be applied through a hose fitted with a nozzle large enough to force a big volume of air through the trunking, and a bag to collect the dirt and dust should be fitted to the outlet.

The inside surfaces of trunking should have one thin coat of paint applied as a preservative, and they should be as smooth as possible so as not to impede the flow of air. Particular care should be taken to see that inlets, outlets, louvres and valves are not clogged with dirt, paint or other obstructions.

A ventilation fan can be fitted to rotate in either direction, and care should be taken to ensure that it is fitted to rotate in the direction which gives the maximum efficiency. Fig. 112 illustrates the correct and incorrect ways of fitting a fan.

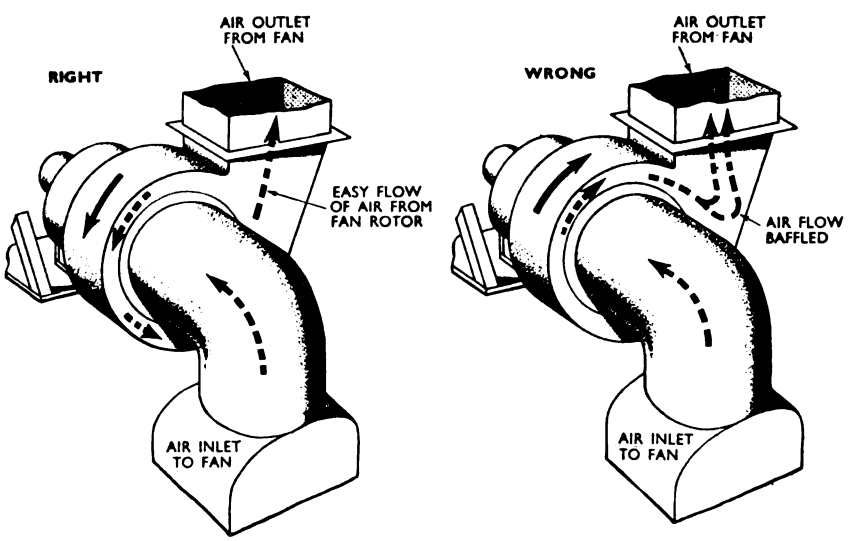

Fig. 112. Right and wrong way of fitting a fan rotor

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Remarks on the use of ventilation systems are given in Chapter XV.

Air-testing of Compartments.—The object of these important tests is to make sure that the compartments are watertight. The best method of providing the necessary air pressure will depend on local conditions, but the following have been found satisfactory :—

(i) in boiler-rooms by using the forced-draught fans, care being taken not to exceed the designed full speed of the fan ;
(ii) in other compartments by using their ventilation supply fans ;
(iii) by using one of the electrically driven, portable, double-bottom fans supplied to the ship, either through a special connection in the hatch or manhole cover or through the main suction fittings of the compartment ;
(iv) by using the ship's low-pressure air system, if fitted ;
(v) by using the dockyard low-pressure air system.

Note.—It is undesirable to use air released from a high-pressure air-bottle, and on no account should a ship's high-pressure air system be used.

For these compressed-air tests a pressure of 2 lb. per sq. in. (equivalent to a water-gauge pressure of 5·4 in.) is ample and need not be exceeded, and a water-gauge pressure of 6 in. should be held after any leaks have been stopped. After the necessary airtightness has been achieved, the fall in pressure should be noted over a period of half an hour, and its rate of fall should not exceed half an inch water-gauge pressure for every ten minutes.

With certain exceptions, periodical air tests of all compartments are required to be carried out by the ship's staff. Fuller information concerning air-testing of watertight compartments will be found in the *Engineering Manual.*

Preservation, Care, and Lubrication of Equipment.—Unpainted iron which is not often used, such as the spare anchor-and-cable gear, is best preserved by coating it with boiled linseed oil after it has been thoroughly cleaned and dried.

Wire hawsers should be lubricated periodically with boiled linseed oil, petroleum jelly or tallow ; on no account should any acid be allowed to come in contact with them. After use, and before they are stowed on their reels, wire hawsers should be rubbed over with fresh water to remove any salt, and then be dried and lubricated.

Standing rigging should be blacked-down occasionally with Stockholm tar, or a mixture of Stauffer's grease and plumbago ; the latter, however, is liable to melt in hot climates or in the vicinity of the funnels.

Lubricants for the wire ropes of lifts, cranes, and other hoists are specified in the various handbooks and in *Admiralty Fleet Orders.* They usually consist of a mixture of grease and plumbago or graphite.

Various kinds of grease are provided for the bearings of capstans, cranes, winches, electrical motors, lifts and other appliances, and care should be taken to use the correct one. The basic constituents of greases differ and particular care should be taken not to mix them ; grease of Admiralty Pattern No. 861, for example, has a lime base, whereas Belmoline R.B. grease has a soda base.

The same remarks apply to the various grades of oil recommended for gear boxes and similar parts of a mechanical system. If there is any doubt as to the similarity between one oil and another, the old oil should be completely drained and flushed out before the new oil is applied.

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As oakum, cotton-waste, cleaning-cloth and thick flannel are liable to shed strands and threads when used for cleaning, they should not be used where such strands can choke pump-strainers, pipes or drains.

Intense cold tends to make steel wire rope and cordage brittle, and this should be borne in mind when using lifting or handling gear in very cold weather. The effect is more pronounced in small ropes than in large ones. Particular attention should be paid to anything subjected to bending stresses, such as the eyes of strops, ropes which pass round small sheaves and eye-plates. This brittleness is not permanent, it goes on return to normal temperatures.

A wire rope which runs round the sheaves of any lifting or handling apparatus is considered to have spent half its life when any one wire of any strand breaks ; the rope should then be examined more frequently, and if used for hoisting it should be discarded if more than ten per cent. of its wires are broken in a length equal to two and a half times the circumference of the rope ; for example, 3-in., 6 × 24 wire rope should be discarded if 15 broken wires are found in a length of 7½ inches. Should a suspiciously large proportion of the breaks appear in one strand, less than the above number of broken wires will warrant the rope being discarded.

(For the care of cordage and wire rope, and for notes on general maintenance, see pp. 145 to 166 and Chapter XV respectively of Volume II of this manual.)

Refitting

The term " refit " as used here includes docking, periodical refit, large refit, reconstruction and conversion, and any other repairs, alterations or additions to which a ship is subjected while in a dockyard.

From the time a ship first commissions to the time she ends her life as a naval unit and is put up for sale to the ship-breakers she is given a normal refit at regular intervals of from one to two years, depending on her type, and a large refit at intervals of from about 5 to 9 years, according to her age. Her hull and equipment are also surveyed at regular intervals to ascertain their condition, and in certain cases to estimate the remaining length of her useful life.

For accounting purposes refits are classed according to their cost, and they are referred to generally by the sub-headings of their respective classes. The various classes are shown below ; the demarcation between them, in terms of money, is published in *Admiralty Fleet Orders*.

SUB-HEAD	DESCRIPTION
D1	Reconstruction, modernisation and conversion.
D2	Large repairs of ships paid off into dockyard control.
D3 (*a*), (*b*) and (*c*) ...	Routine and other refits, intermediate dockings, and small repairs.
D4	Repairs to tugs and yard craft.

Note.—Sub-heads *a*, *b* and *c*, are allocated to ships under construction and denote respectively " dockyard-built ships," " contract-built ships," and " other vessels."

Definitions of Refitting Terms

A periodical refit is the overhaul of a ship by a dockyard at regular intervals, and such a refit is required to be completed in a stated period. The length of the interval depends on the type of ship : 2 years for battleships, aircraft

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carriers and cruisers; about 16 months for destroyers and frigates; 12 months for depot ships and repair ships; and 18 months for submarines. Such refits include docking and are classed as 'D3.'

An intermediate docking is the docking of a ship in a dry-dock between periodical refits to clean and repaint her bottom, and to inspect and repair her underwater fittings. The length of the interval between successive dockings depends on the type of ship; 12 months for battleships, aircraft carriers and cruisers; from 6 to 8 months for destroyers and frigates; and 6 months for submarines. Depot and repair ships are usually docked only during their periodical refits.

Self refit describes the minor repairs undertaken by the ship's staff or by the staff of a depot or repair ship, when the ship is in a dockyard (during leave periods, for example), or with her parent ship. For urgent repairs in out-of-the-way places a ship may be placed "out of routine" for a self-refit.

Large repairs describes the extensive refit carried out at intervals of from five to ten years, the interval depending partly on the age and state of the ship and partly on her type, and therefore being irregular. For such refits, which are classed as 'D2,' the smaller ships may remain in commission with a reduced complement, but the larger ships are destored and paid off into "dockyard control."

Reconstruction and modernisation is the incorporation in a ship of all the latest alterations and improvements; it is usually of a very extensive nature, involving sometimes the installation of new machinery and boilers as well as the renewal of much of her armament and equipment. For such refits, classed as 'D1,' the ship is destored and paid off into dockyard control.

Surveys, other than the routine surveys carried out by the ship's staff which have already been described, comprise a thorough examination by the dockyard of the ship's hull and its equipment and fittings to determine their state and to make good any of it which is defective. A ship may also be specially surveyed for the purpose of estimating how much longer she will remain effective. Such surveys are combined with a periodical refit, and may be spread over successive refits, but they must be so organised that each part of the hull and each fitting or item of equipment is surveyed within the prescribed period.

Surveys are carried out by the dockyard as follows:—

battleships, aircraft carriers and cruisers	at intervals of from 4 to 5 years;
destroyers, frigates, and similar vessels whose bottom plating is:—	
over ¼-in. thick	during alternate dockyard refits;
¼-in. thick or less at any part ...	during each dockyard refit;
submarines	during each dockyard refit;
coastal forces craft	during each dockyard refit.

In addition to the hull survey, hydraulic gun mountings are surveyed annually, and machinery, boilers and general equipment are surveyed during large repairs.

Reports of all surveys carried out by a dockyard are rendered on *Form D.*171, and a copy is kept in the *Ship's Book*.

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PREPARATIONS FOR REFITS

Refit Conference.—As soon as possible after the ship arrives in a dockyard for a refit, a conference is held between the ship's officers and the dockyard officers; it is presided over by the Superintendent of the Dockyard or his deputy, the Captain or Commander of the Dockyard. At this conference the ship's defect lists and the list of approved alterations and additions are discussed in detail, and decisions are made as to which items shall be undertaken during the refit, the division of work between the dockyard and the ship's staff is agreed upon, and the refit programme is arranged. The results of the conference are then recorded on *Form D.*392.

Periodical Refits (D3).—The principal arrangements for a typical D3 refit include: allocation to a berth under a crane for a part or the whole of the refit period depending on what lifting is required; dates and times of moving the ship from one berth to another; dates and times of docking and undocking; provision of locked storage in the ship for workmen's tool boxes; dates of the start and finish of any work in spaces or compartments, such as mess decks, bathrooms, galleys and store-rooms, and arranging them to fit in with the ship's programme of leave, storing, ammunitioning, etc; provision of any portable boilers and shore galleys required; clearing stores or equipment from compartments which are to be surveyed, tested or repaired, and providing " lay-apart " store houses for them on shore; and finally the date of sailing and the programme for any trials.

Large Refit (D2) and Reconstruction (D1).—For ships undergoing large repairs a small party of naval officers and ratings is usually drafted to the ship from the local barracks for care and maintenance duties, and for inspecting and accepting tests and repairs.

The ship should arrive at her refitting port with only sufficient fuel for carrying out any trials before she is paid off, and any oil fuel or other tanks which are to be surveyed must be emptied, cleaned out, and freed of gas before the ship is handed over to dockyard control.

A steaming trial may be carried out to test the state of the boilers and machinery and to discover any undetected defects, and a gunnery equipment trial may also be carried out for the same purposes. These trials are attended by dockyard officers.

Before the ship is paid off the ship's staff are responsible for :—

(i) landing and returning to store all ammunition, explosives, armament stores, naval stores and victualling stores, whether in the store-rooms or issued on permanent loan;

(ii) removing all W/T and radar equipment, except the aerials, and returning it to store;

(iii) preparing all spare gear and readily portable fittings for storage and placing them in a lay-apart store on shore;

(iv) checking the fixture lists with dockyard officers, and clearing the ship's stores accounts;

(v) landing the ship's boats and returning them to the dockyard;

(vi) cleaning out all watertight compartments, store-rooms and living spaces; cleaning and drying out all tanks and the bilges; putting all such places in a state of preservation;

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(vii) putting all auxiliary machinery, and any fittings liable to deteriorate, in a state of preservation ;

(viii) providing dockyard officers with copies of the latest reports of surveys and tests, and handing over the *Ship's Book* and all " as fitted " drawings ;

(ix) ensuring that all surveys, tests and examinations due to be carried out have been entered accordingly in the ship's defect lists ;

(x) handing over all the ship's keys to the Captain of the Dockyard ;

(xi) providing Pink and White defect lists.

When all this has been done the ship is inspected throughout by the dockyard officers in company with the ship's officers, and if the former are satisfied that all the necessary work has been carried out the ship is paid off and placed under dockyard control.

Preparation for Acceptance into Reserve

In peace a " reserve " of ships, known as the Reserve Fleet, must be maintained in a state in which they can rapidly be prepared for service in an emergency.

As it would be impossible to bring all ships in reserve to a state of readiness at the same time, each is placed in one of four different categories according to her condition at the time of paying off. These four categories are explained below.

Category 'A,' Operational Reserve, consisting of ships fit for full operational service at very short notice, and all of which will probably be required for full operational service shortly after mobilization.

Category ' B,' Supplementary Reserve, consisting of ships required for full operational service shortly after mobilization, but which will probably not be commissioned until after those of category ' A.'

Category ' C,' Extended Reserve, consisting of ships required for further service, but which will not be commissioned until after those of categories ' A ' and ' B.'

Category ' Z,' Disposal List, being ships no longer required for service.

Ships in categories ' A ' and ' B ' are refitted and docked at the standard intervals ; those in category ' C ' are docked only as necessary to preserve them, and are given such limited refits as the resources of the dockyards allow. Ships in category ' Z ' are not refitted, docked or otherwise maintained, because they will probably be either broken up or used as targets.

Stores and ammunition are kept on board ships of categories ' A ' and ' B,' except that certain portable, valuable, attractive or perishable stores are landed ; ships in category ' C ' are usually destored. Ships in category ' Z ' are destored and de-ammunitioned, and they are stripped of their portable fittings and equipment when these are required for other services.

Ships of the Reserve Fleet except those of category ' Z ' are manned by skeleton crews who maintain them in the required state of preservation, but before being paid off into reserve they are put into a thorough state of preservation by their sea-going crew in order to reduce maintenance work to a minimum.

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Details of the states of preservation required are given in the *Reserve Fleet General Orders.*

When a ship is ordered to " reduce to reserve " she should undergo a full power trial of two hours' duration, also comprehensive trials of all her equipment while she still has her full complement on board. As a result of these trials a comprehensive defect list is compiled for use the next time the ship is refitted, and a concise report on the condition of the ship is made to the Admiralty so that the category in which the ship is to be placed can be determined.

When practicable, ships are refitted before they are placed in reserve, but this depends upon what refitting facilities are available in the dockyards at the time.

In addition to the normal methods of preservation, such as draining and drying out pipe-systems and compartments, cleaning and painting the structure and fixed fittings, and cleaning and greasing equipment and movable fittings, all working equipment on the weather decks, such as the armament and deck machinery, is completely enclosed in plastic covers. In certain ships of categories ' B ' and ' C ' all openings to the atmosphere are sealed and the ship is " dehumidified." This process reduces the relative humidity within the ship to between 25 and 30 per cent. and prevents all deterioration of structure and fittings inside the ship.

Dehumidification is a process in which the air within the ship is kept dry and in continuous circulation. The air is drawn by a fan from an interior position high up in the ship, passed through a dehumidifying machine which dries it by means of desiccants such as " silica gel " or " activated alumina," and then circulated throughout the ship by means of the firemain or some other suitable pipe system. The air then returns naturally to its source through hatches, doors, manholes and other openings in the decks and bulkheads, those left open being selected so as to make the return path of the air as long as possible. During its return the air collects any moisture in the compartments through which it passes and this is extracted from it as it again passes through the dehumidifying machine.

After a time the desiccant in the machine becomes saturated, but it is then dried automatically by passing hot, dry air through it. It is essential for a ship to be thoroughly dried out before starting the dehumidifying machine, and this may take several weeks, depending on the labour available.

Trials

The extent of trials after refitting depends on the extent of the refit. After a normal periodical refit, inspections, tests and trials are usually confined to compartments, equipment and machinery which have been repaired or in which any alterations have been made. After large repairs or reconstruction, and sometimes when a ship is commissioned from the reserve, the trials are more comprehensive ; in addition to testing each individual item of equipment they will include a basin trial of the main machinery, and a full range of sea trials, *e.g.*, full power and fuel consumption trials, starting, stopping and astern trials, gun and torpedo firings, trials of radio equipment, and swinging ship for the adjustment of compasses.

The programme for such trials is arranged jointly by the ship's officers and the dockyard officers.

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Dockyard Organisation

The following notes on the organisation of a Royal Dockyard are intended to give a ship's officer some idea of the division of duties and responsibilities among the various dockyard officers and their departments, so that when he is faced with a particular problem he will know to whom he should go for advice.

The Superintendent of the Dockyard is a senior naval officer, the title of Superintendent being added to that of his naval rank, *e.g.*, Admiral Superintendent, Commodore Superintendent, Captain Superintendent. He is responsible for administering the dockyard in accordance with the instructions laid down in the *Home Dockyard Regulations, Regulations for Dockyards Abroad*, and *Dockyard War Instructions.*

The Captain (or Commander) of the Dockyard and Queen's Harbour Master (*C.D.* and *Q.H.M.*) is a naval officer of Captain's or Commander's rank who is deputy to the Superintendent. He is responsible for moorings, berthing arrangements, movements of ships, pilotage, tugs, compass adjustments, rigging and canvas and bunting work. The Captain of the Dockyard is also responsible for the administration of ships paid off and placed under dockyard control for large refits. He is assisted by a number of naval officers, including the Assistant Q.H.M., Assistant C.D., and those responsible for the movement and mooring of shipping, also by specialist officers, such as Engineer, Gunnery and Shipwright officers, and the Master Rigger. He is also assisted by civilian officers, such as Foremen and Inspectors of Sailmakers, and Inspectors of Riggers.

The Manager, Constructive Department (*M.C.D.*) or *Chief Constructor* (*C.C.*) is a senior civilian officer who is responsible for the construction of ships and for fitting them out with:- all accommodation, including galleys, bathrooms and store-rooms; water services; ventilation arrangements; pumping, flooding and draining arrangements; magazine stowages; boats, derricks, cranes, winches, capstans, anchors and cables; masts and yards; accommodation and other ladders; and similar equipment. He is also responsible for refitting and repairing ships and their equipment in these respects. The M.C.D. is assisted by a number of civilian officers: Constructors, Senior Foremen of the Yard, Foremen of the Yard, Foremen of Trades, and Inspectors, for example. He is also assisted by the Boatswain of the Yard, who is a naval officer and in charge of the labourers for cleaning the yard and ships, and of the slingers and stage makers in the Constructive Department.

The Manager, Engineering Department (*M.E.D.*) or *Chief Engineer* (*C.E.*) is a senior naval engineer officer who is responsible for the installation and repair of main and auxiliary machinery and boilers in ships, gun mountings and directors, torpedo tubes, and ventilation in machinery spaces; he is also responsible for the maintenance of yard machinery, including dock pumps, cranes and air compressors, and for machinery in naval shore establishments. Rope making is undertaken at Chatham Dockyard under the supervision of the M.E.D.

The M.E.D. is assisted by naval engineer officers, and civilian officers, such as Senior Foremen of the Engineering Branch, Foremen, and Inspectors.

The Electrical Engineering Manager (*E.E.M.*) or *Superintending Electrical Engineer* (*S.E.E.*) is a senior civilian officer who is responsible for the repair and refitting of all electrical installations in ships, and in general for the electrical

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installations in dockyards and naval shore establishments, including generating stations and the supply of current. The E.E.M. is assisted by naval officers and by civilian officers, such as Electrical Engineers, Electrical Station Engineers, Foremen of the Electrical Branch, and Inspectors.

The Superintending Civil Engineer (*S.C.E.*) or *Civil Engineer* (*C.E.*) is a civilian officer who is responsible for the maintenance of all buildings, and for shore construction in yards and shore establishments, including basins, jetties, wharves, sea walls, graving docks, roads, railways, etc.; he also carries out land surveys and dredging, and arranges the supply of water.

The S.C.E. is assisted by civilian officers such as Civil Engineers, Surveyors and Foremen of Works.

The Superintending Naval Store Officer (*S.N.S.O.*) *or Naval Store Officer* (*N.S.O.*) is a civilian officer who is responsible for obtaining, storing and supplying all naval stores, including oil fuel, for ships and naval shore establishments. He is also responsible for transport, including motor transport, and for arranging for the shipment or air carriage of naval stores and equipment. The S.N.S.O. is assisted by civilian officers such as Naval Store Officers, Deputy Naval Store Officers, Foremen of Storehouses, and Inspectors of Storehousemen; also at certain yards at home by an Assistant Fuelling Officer.

The " warrant section " of the Naval Store Department in dockyards deals primarily with ships' requirements, and any enquiries about sea stores should be made initially to this section.

The Surveyor of Stores (*S of S*) is a civilian officer who is responsible for the survey and inspection of all stores when they are first received, unless dealt with under special regulations, and of all stores returned from H.M. ships and establishments.

The Expense Accounts Officer (*E.A.O.*) is a civilian who is responsible for accounting for all expenditure in the yard, for recording all work done in the dockyard, and for compiling returns of expenditure as required by the regulations.

The Cashier is a civilian officer who is responsible for the payment of salaries and wages of all officers and men of the dockyard.

The Torpedo Engineer Officer (*T.E.O.*) is a naval officer of the Engineering Branch who is responsible for the maintenance, adjustment, repair, storage and supply of torpedoes and paravanes.

The Senior Armament Supply Officer (*S.A.S.O.*) or *Armament Supply Officer* (*A.S.O.*) is a civilian who is responsible for the storage and supply of guns, weapons, ammunition and explosives of all kinds.

The Senior Victualling Store Officer (*S.V.S.O.*) or *Victualling Store Officer* (*V.S.O.*) is a civilian who is responsible for the storage and supply of all victuals and provisions.

The workmen employed in the dockyards are of many trades and grades; they include shipwrights, carpenters, joiners, plumbers, painters, ship-fitters, engine-fitters, boilermakers, coppersmiths, smiths, founders, blockmakers, electrical fitters, wiremen, hosemakers, drillers, riveters, caulkers, welders, bricklayers, masons, storehousemen, skilled labourers and labourers. Their work is supervised by Senior Foremen, Foremen of Trades, and Inspectors.

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SUMMARY OF PERIODICAL EXAMINATIONS, SURVEYS AND TESTS OF UPPER-DECK GEAR AND LIFTING APPLIANCES IN SEA-GOING SHIPS

PARTICULARS OF EQUIPMENT	EXAMINATIONS TO WHICH SUBJECTED	WHEN CARRIED OUT AND REMARKS
Anchors and cables and associated gear.	Inspection.	Monthly—by ship's staff. The movable arms of anchors should be moved and lubricated.
	Survey.	Every six months for submarines, fishery protection vessels, minesweepers, and all vessels, except those mentioned below, which generally lie at their anchors—by ship's staff assisted by dockyard.
	Survey and inspection.	Yearly for destroyers, drifters, tugs, sea-going yard craft, and all vessels, except those mentioned above, which generally lie at moorings—by ship's staff assisted by dockyard. The joining shackles of the cables should be inspected every six months by ship's staff.
	Heat treatment, retest and examination.	Every 3½ years maximum for ships with cables of 2¾ in. and over, 3 to 4 years for ships with cables under 2¾ in., and 2½ to 3 years for ships on stations abroad which return to home ports for recommissioning—by dockyard.
Paravane towing chains, slips and gear.	Survey. Test.	Every six months—by ship's staff. Yearly—by dockyard.
Wire hawsers, rigging screws and standing rigging.	Survey.	Every six months—by ship's staff. Repairs carried out with dockyard assistance if necessary.
Any derricks, davits, winches and geared blocks which are used for hoisting or handling torpedoes, explosives, ammunition or paravanes, and all minesweeping gear.	Test.	Yearly—by dockyard.
Geared blocks other than those mentioned above.	Test.	Every two years—by dockyard.
Boats' davits and all associated winches, blocks and gear.	Test.	Every two years—by dockyard.
Boats' slings and associated equipment.	Test and survey.	Yearly, and also after repair by ship's staff—by dockyard. Associated fittings in the boats are surveyed at the same time, and reported on *Form S.*1231.
Cranes.	Test.	Yearly—by dockyard.
Crane and wire lift-ropes.	Test.	Yearly if practicable, but interval should not exceed two years—by dockyard. The ropes are unrove, landed, collected and re-rove by ship's staff.
Aircraft quick-release couplings.	Test.	Yearly—by Portsmouth Dockyard.

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SUMMARY OF PERIODICAL EXAMINATIONS, SURVEYS AND TESTS OF UPPER-DECK GEAR AND LIFTING APPLIANCES IN SEA-GOING SHIPS—*continued.*

PARTICULARS OF EQUIPMENT	EXAMINATIONS TO WHICH SUBJECTED	WHEN CARRIED OUT AND REMARKS
Lifts.	Test. Test and survey.	Quarterly—by ship's staff. The full working load is raised and lowered. Yearly—by dockyard. All associated fittings are surveyed and examined at the same time.
Ribbon strops for torpedoes.	Survey and test. Survey only. Test and survey.	Before issue—by dockyard. Six months after receipt, or test—by ship's staff. Yearly—by dockyard.
Machinery and spare gear lifting appliances.	Test.	When the ship is undergoing a large refit—by dockyard.
Cordage.	Inspection and test.	Should be inspected frequently. Suspect cordage may be sent to dockyard for test as required. Where the purchase of any system is rove with cordage the static load is not to be suspended on the purchase; this is to avoid over-stretching and injuring the cordage. Routine tests of cordage are given in *Naval Store Regulations*.
Hooks.	Test.	Every six months or yearly, according to their use, and if they have not been tested as a component part of a lifting appliance—by dockyard.
Eye-plates and cleats.	Test and survey.	Tested at the same times as the systems with which they are incorporated; if not associated with a system, surveyed yearly and replaced where necessary—by dockyard.
Lifting appliances in submarines.	Test and replacements.	Torpedo lifting gear is tested every six months; other lifting appliances during refits at intervals not exceeding eighteen months—by dockyard. Hoist ropes of periscopes, radar masts, torpedo and boat derricks, and telemotor presses are renewed at each refit—by dockyard.
Lightning conductors.	Inspection and test	At frequent intervals for electrical continuity—by ship's staff.
Ramp hoisting gear of landing ships and craft.	Test and survey.	At alternate docking periods—by dockyard.
Capstans, cableholders, winches and windlasses.	Inspection. Examination	Weekly—by ship's staff. Each machine should be turned round and lubricated. Yearly—by ship's staff. Spindles and deck bushes of capstans and shafts of winches should be inspected. Where applicable the capstan head and its disc are to be parted and inspected.

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CHAPTER XVII

Types and Design of Merchant Ships, and Tonnage Measurement

Types of Merchant Ships

IN A VERY broad sense merchant ships can be classified in two ways :— either as liners and tramps, or as passenger ships and cargo ships.

A liner is any ship which sails to schedule on a definite route for a specific destination, with advertised dates of departure from, and arrival at, specified ports of call along her route, and she can thus be a ship carrying passengers or cargo or both. The term therefore includes not only the ocean-going passenger or cargo liners, but also cross-channel packets and some coasting vessels.

A tramp, as her name implies, is a ship which does not keep to a fixed route or sail to any particular schedule. She is usually purely a cargo vessel which is hired out by her owners under contract to a charterer who, by the terms of his contract, provides her with cargo and specifies her ports of call and the approximate dates of her arrival and departure. Her routes and ports of call are governed solely by the availability of suitable cargoes, and as these must vary considerably, both seasonally and geographically, she may roam over the oceans for a long time before returning to her home port.

The interests of passengers, as regards both safety and comfort, are protected by law, and any British ship which carries more than 12 passengers must have a passenger certificate issued by the Ministry of Transport ; she can therefore be classed as a passenger ship, although she may carry cargo as well. To qualify for the certificate the ship must conform to certain minimum standards in regard to her hull structure, watertight sub-division, life-saving and fire-fighting equipment, and passenger accommodation. These standards are modified to a certain degree in vessels such as cross-channel packets, coasters, ships engaged in the pilgrim trade, pleasure steamers, and vessels plying in sheltered waters.

Sea-going ships which carry cargo and less than 13 passengers do not require a passenger certificate and so need not conform to any legal structural standards except those laid down by the Load Line Rules for all sea-going vessels, and such ships can be classed as cargo vessels. They are, however, generally built to the minimum standards of construction laid down by the Classification Societies for purposes of insurance, and have to conform to certain minimum legal standards of accommodation, and of life-saving and fire-fighting equipment.

Apart from these broad methods of classification merchant ships can be classified under the following well-established types :—

The passenger liner which is designed for the transatlantic passenger trade between Europe and North America, and which runs to a strict schedule of times of arrival and departure at her terminal ports. Usually of 20,000 tons gross and above, more than 600 feet in length and with a speed of over 20 knots, the carrying capacity of these vessels is almost entirely devoted to passengers and their needs, but most carry mails and a

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small amount of cargo as well. An example of the upper limit of this type is the Cunard liner *Queen Elizabeth*, which has a gross tonnage of 83,673, an overall length of 1,031 feet, and a maximum speed of over 32 knots.

The passenger and cargo liner which is designed for the passenger and cargo trades between Europe and the rest of the world. Her voyage between her terminal ports is usually a long one and she may call at several ports along her route. The gross tonnage of such ships varies from 8,000 to 30,000, their length from 400 to 750 feet, and their speed from 13 to 25 knots. Their carrying capacity is divided between passengers and cargo, and they usually carry mails as well. Examples of this type are ships of the P. & O. and Orient lines plying between England and the Far East, and of the Union Castle line plying between England and South Africa.

The cargo liner which is virtually an ocean-going cargo ship, but because she plies on a fixed route to an advertised schedule she usually has accommodation for a small number of passengers. Such ships are usually designed for the route on which it is intended they should ply and for the types of cargo they are liable to carry, and their size and type therefore vary considerably. Broadly speaking, however, they are between 2,000 and 20,000 tons gross, with speeds of between 10 and 15 knots, and between 200 and 600 feet in length. Most of them are designed to carry a general cargo, though they may occasionally carry bulk cargoes, and some are built to carry perishable commodities such as meat, eggs, dairy produce, and fruit in refrigerated holds. The number of passengers is usually limited to 12, because apart from providing the necessary accommodation this entails little extra constructional or running expenses. Examples of this type are ships of the Clan line carrying general cargoes between England, Europe and the Far East, " refrigerator ships " of the Port line carrying chilled and frozen meat from New Zealand and Australia to England, and the " banana boats " of Elders and Fyffes, Ltd. carrying bananas and other fruit from the West Indies to England.

Tramps are usually designed to carry bulk cargoes such as grain, clay, cement, nuts, salt, ores and bitumen, though they may also be chartered to carry a general cargo. Some of these ships can carry several types of bulk cargo, but others are designed for a particular trade, such as the ore ships which are specially fitted and strongly constructed for the carriage of this dense type of cargo, and colliers which often carry coal on the outward voyage and grain on the return voyage. Accommodation for passengers is not usually provided in these ships because they seldom ply on a fixed route. The general purpose tramps must be large enough to carry a worth-while amount of cargo and weather the storms of any ocean they may have to cross, and yet they must not be too large to enter the smaller ports of the world. For these reasons their gross tonnage is usually between 2,000 and 10,000. While speed is a desirable quality in a tramp it considerably increases her running costs, which must be kept as low as possible. Improvements in material, machinery, fuel and methods of construction, however, have enabled the designer to increase the speed of the average tramp from about 9 knots in 1910 to as much as 12 or 14 knots in 1953.

Tankers are ships specially built to carry a liquid cargo in bulk and they usually ply on a fixed route with few intermediate ports of call.

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They vary very greatly in size, from the 2,000 ton coaster to the monster ships of over 40,000 tons gross, but the average ocean-going tanker is of from 10,000 to 15,000 tons gross. Their speed also varies greatly, from 10 to as much as 20 knots. Though plying on a fixed route tankers are not usually provided with accommodation for passengers because of the highly inflammable nature of their cargo and the consequent risk of fire.

The operation of a tanker fleet differs greatly from that of a fleet of cargo liners. A tanker can very seldom get a return cargo, and it is therefore quite usual for her to discharge a full cargo, load with ballast, bunkers and stores, and sail on the return voyage within from 48 to 60 hours of arriving at her destination, and her turn around at her loading port may not take much longer. A tanker therefore spends much less time in port and much more time at sea than does a cargo liner, and her quick turn arounds considerably complicate the organisation for routine overhauls and running repairs, which in a cargo liner can be carried out during the comparatively long periods when she is in port loading or discharging cargo. Owing to the great risk of fire or explosion, moreover, no repairs which could cause sparks can be undertaken in a tanker until she is entirely freed of inflammable or explosive gases. To run a fleet of tankers economically and efficiently careful planning of all examinations, overhauls, periodical dry dockings, and surveys is necessary to ensure that each ship will be out of service for as short a time as possible.

Coasters are virtually small cargo liners or tramps built for the coastal trade of a country or for short sea voyages, such as those across the North Sea or the Channel, and some may carry a limited number of passengers. Their size is seldom greater than 3,000 tons gross and their speed is usually between seven and eleven knots.

Packets are small, fast vessels built principally for the passenger trade for short sea voyages, such as the cross-channel services between England and France, and England and Ireland, and the North Sea services to Belgium, Holland and the Scandinavian countries. They are usually owned by Railway Companies, sail to a strict schedule to link with the train services of the countries between which they ply, and they also carry mail and a small amount of cargo. Their size may vary from the 500-ton Isle of Wight steamers to the 3,000-ton cross-channel ships, their speed may be from 10 to 25 knots, and they are usually of shallow draught and very handy for manœuvring in the confined and shallow ports between which they ply.

Of these types it is intended only to describe here the conventional cargo vessel and the tanker.

The Cargo Vessel

The earliest type of cargo steamer was a " flush decker," in which the openings above the engine and boiler rooms were surrounded by low casings fitted with skylights to admit light and air. Experience showed that this form of hull was dangerous, and so light superstructures extending from side to side of the ship were built round the machinery casings. A further development was the addition of a forecastle and poop, for improved seaworthiness, which in turn led to the well-known " three-island " type of cargo vessel with forecastle, bridge and poop superstructures, and before and abaft the bridge a well-deck protected by bulwarks and well suited for the carriage of deck

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cargoes such as timber. Variations of the three-island type are the " shelter-deck " ship in which all three superstructures are extended to form a continuous non-watertight superstructure from bow to stern, thus providing a sheltered stowage which is not included in the net or register tonnage and is therefore exempt from harbour dues when no cargo is carried in the superstructure spaces ; " well-deck " ships in which the poop is extended to join the bridge ; and the " raised quarterdeck " ship in which the upper deck abaft the bridge superstructure is raised a foot or so to provide more cargo space aft.

Most cargo liners are nowadays (1953) equipped with one or more " deep tanks," which are situated amidships, extend the full width of the ship and have their tops usually level with the 'tween decks. These tanks serve the double purpose of enabling the ship to carry a part cargo of liquid in bulk and of improving her seaworthiness when in ballast or lightly loaded.

The capacity of these tanks varies from 500 to 1,000 tons deadweight, and they are usually divided longitudinally by one or more liquid-tight bulk-heads into two or more compartments so that different liquids can be carried and the free-surface effect of the liquids be reduced. Their use is not, however, confined to the carriage of liquids alone ; they can be used for carrying bulk cargo or general cargo, and for this reason they are fitted with large removable lids or hatches.

These tanks are particularly useful for water ballast when the ship is lightly laden, because when completely filled with sea water they give the ship the necessary degree of immersion without unduly lowering her centre of gravity. Ships which are not fitted with deep tanks and have all their ballast tanks in their double bottoms are liable to be unduly stiff when lightly laden, because all the weight is concentrated low down in the ship.

The size and weight of individual items of cargo which can be handled in a cargo liner depend on the size of her hatchways, the strength of her derricks and the power of her winches. The size of cargo hatches varies, but a length of 30 ft. and a breadth of 20 ft. are about average dimensions. The normal derrick provided has a maximum safe working load of 5 tons, and its winch should be capable of hoisting a load of one ton at a speed of 250 ft. per min. For loads of up to one ton the derrick is rigged with a whip or runner, but for greater loads it is rigged with a double whip or a purchase. Many ships are equipped with one, and sometimes two, heavy-lift or " jumbo " derricks, and the maximum load they can lift varies from 10 to 30 tons. A few ships are specially constructed and equipped for extra heavy lifts of from 50 tons to as much as 150 tons ; they are provided with special ballasting arrangements to ensure that they have the necessary margin of stability when hoisting heavy loads out or in. From two to four derricks, each with its own winch, are usually provided for each hold ; and when working at full speed under ideal conditions about 20 tons of cargo per hour can be handled at each hatch.

Tankers

The layout of a typical tanker of the three-island type is shown in Fig. 113. The islands are part of the hull structure and are watertight, thus giving the ship an additional reserve of buoyancy.

The officers are accommodated in the bridge superstructure, and in the after superstructure are the crew's accommodation, galleys, wash places and

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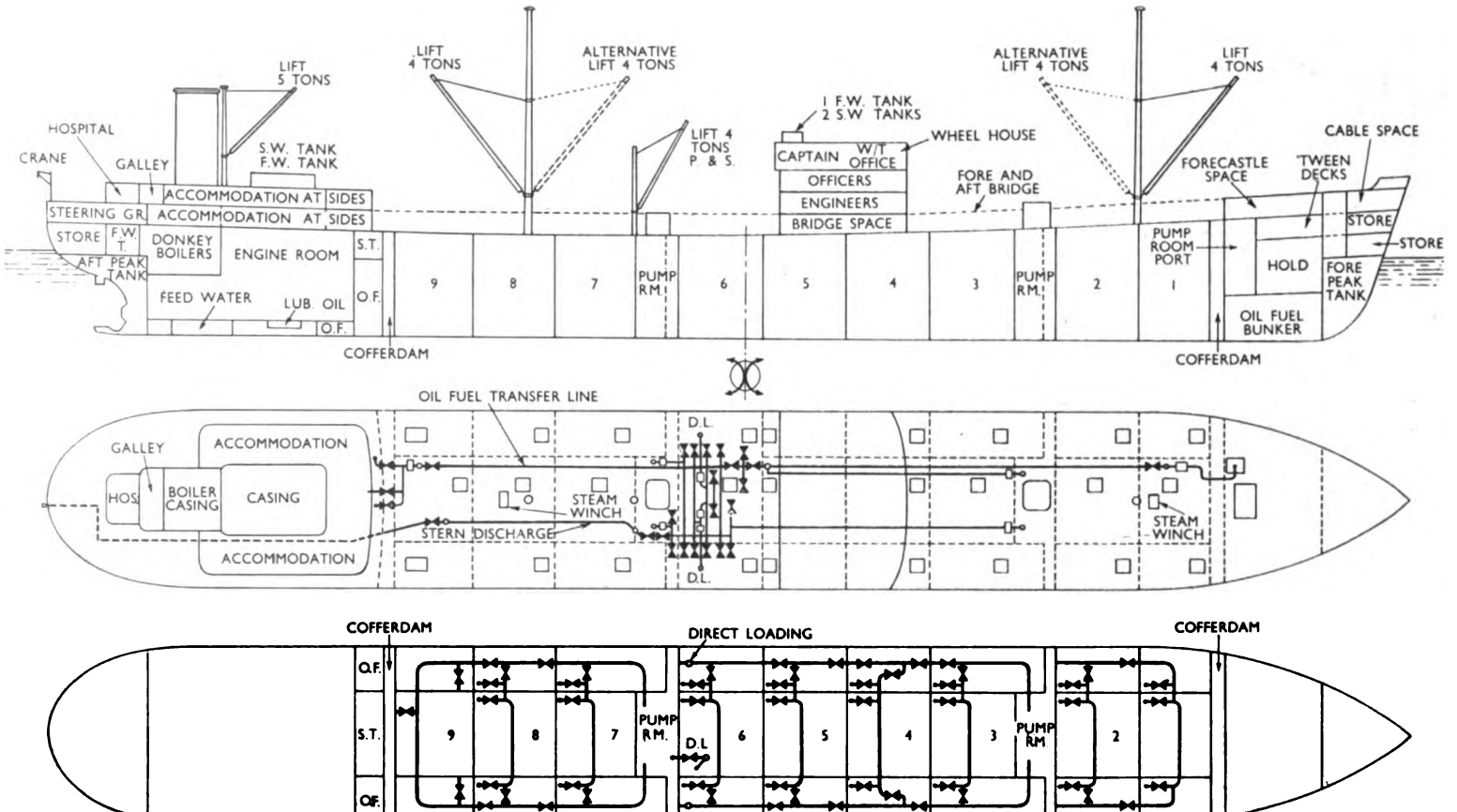

Fig. 113. Layout of a typical tanker

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officers' smoke-room. This distribution lessens the risk of fire from indiscriminate smoking or from the galley fires.

The machinery is situated right aft to minimise the danger of fire from sparks from the funnel and also to obviate the difficulty of constructing the long, oil-tight or spirit-tight shaft tunnel which would be necessary in a ship with her engines amidships.

The minimum freeboard allowed by the load-line regulations for tankers is much less than that allowed for the ordinary cargo vessel, and the poop, bridge and forecastle of a tanker are therefore connected by a fore-and-aft bridge to allow the crew to pass from one island to another in safety when the ship is loaded to her marks and in a seaway. This deeper loading is permitted for the following reasons :—

(i) the cargo hatches are very small, being used only for access and to admit light and air at certain times ;

(ii) the hatch covers are made of steel, are as strong as the deck plating, and are very securely fastened down by drop-bolts and wing-nuts to form a packed, oil-tight joint with the hatch coaming ;

(iii) there are no large, open ventilators leading to the cargo compartments ;

(iv) the cargo spaces, when loaded, have a very low " permeability " ; *i.e.*, there is very little room for any water which may enter them because they are already nearly full of liquid ;

(v) the ship is sub-divided into an unusually large number of watertight compartments.

The fore-and-aft bridge also forms a convenient support for the numerous pipelines which run along the upper deck, which are : the main cargo line, the steam and exhaust lines, the steam smothering line, the wash-deck line, the vapour line, and the oil-fuel transfer line. In addition, there are the main electricity supply leads, telemotor pipes for the steering gear, and telephone and telegraph leads.

The cargo-carrying part of the hull is sub-divided into a number of oil-tight or spirit-tight tanks, these being arranged in groups which are separated from each other and from the bow and stern parts of the ship by spaces called " cofferdams." These cofferdams prevent liquid from one group of tanks leaking into another, or into the forward and after sections of the ship, and they thus allow of the carriage of two or three different kinds of petroleum products at the same time. Those between groups of tanks are made large enough to house the cargo pumps and they therefore serve the dual purpose of cofferdams and pump-rooms.

In the older type of tanker the difficulty of reducing the adverse effect of free-surface liquid on the stability of the ship, and at the same time allowing for the considerable expansion or contraction of petroleum products caused by a change of temperature, was overcome by fitting a trunk at the crown of each tank with its top level with the upper deck, and then filling the tank to within a few feet of the top of its trunk. The 'tween deck spaces thus formed between the central trunk and the sides of the hull were made into what were called " summer tanks " which could be filled to bring the ship down to her marks when carrying a cargo of light oil. In the modern tanker this difficulty is overcome by dividing each tank into three or more compartments by longitudinal bulkheads, and allowing in each tank an ullage of about two per cent. of its capacity.

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As in any ship with her machinery right aft, her trim is difficult to adjust and control when loading and discharging, particularly when part cargoes have to be discharged at different ports. Another trimming problem is caused by the consumption of oil fuel on passage and this is overcome by providing a deep tank for oil fuel right forward; as fuel in the cross-bunker situated immediately before the engine-room is used, the bunker is topped up with oil transferred from the forward deep tank, thus lightening the bows.

When a tanker has discharged her cargo and sails empty she is ballasted by flooding sufficient tanks with sea water to give her the required trim and draught.

Cargo is loaded and discharged through a system of piping by means of steam-driven cargo pumps. The system is so arranged that different grades of cargo can be loaded or discharged simultaneously without risk of their mixing; cargo or water ballast can be transferred from one tank to another; tanks can be filled with water ballast; and the pipelines can be washed out. Each pump should be capable of delivering 400 to 500 tons per hour against a back-pressure of 100 lb. per sq. in. The system consists of piping led along near the bottoms of the tanks and connected by risers to the main cargo line on deck, and some ships are fitted in addition with a direct loading and discharge line to each tank. To enable the tanks to be completely emptied they are also provided with a drainage system, which is brought into use when the tank is nearly empty, the main discharge pump then being switched to another tank. In addition to these pumping arrangements each tank is fitted with steam-heating coils for reducing the viscosity of heavy oils in cold weather and thus facilitating their flow through the pumping systems.

The amount of cargo in each tank is usually measured by an ullage stick or steel tape which works in a perforated pipe and passes through an ullage plug fitted in the crown of the tank. The readings thus obtained are compared with a table provided by the builders which, in addition to giving the quantities of cargo in the tank corresponding to every six inches of ullage, gives the quantities of cargo for different depths obtained by sounding.

Tanks are vented to allow the air to escape or enter as they are filled or emptied, and to enable any inflammable or explosive gases generated by the cargo to escape safely, by leading a 4-in. pipe, fitted with a shut-off valve, from the crown of each tank to one of several 6-in. main vapour lines. These main lines run fore and aft along the upper deck and then up the masts to a height of not less than 12 feet above the steaming lights, and each is fitted with a gooseneck and a flame arrester at its outlet.

In addition to the normal fire-fighting arrangements provided by hand extinguishers and the wash-deck service, two steam systems and an emergency air system are usually provided.

The steam smothering system consists of a 4-in. pipe which is led from the main boilers through a master-control valve at the forward end of the poop and then along the fore-and-aft bridge, and from this pipe a branch pipe is led to the crown of each tank. The other steam system, which is used chiefly for cleaning out the tanks, consists of 1-in. perforated pipes extending from the crowns of the tanks to within four feet of their bottoms; these pipes are connected through stop valves to the deck steam line which is fed by the donkey boilers.

The emergency air service consists of a $1\frac{1}{2}$-in. pipeline led from the engine-room along the fore-and-aft bridge to the forecastle, and it is fed either through

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reducing valves from the high pressure air storage tanks in the engine-room, or by a diesel-driven air compressor situated in the forecastle. The pipeline is fitted at intervals with cocks and connections from which portable hoses can be led to a cock in the crown of each tank. The emergency air service can also be connected to the deck steam line to enable the cargo pumps, deck auxiliary engines, and steering gear to be worked by air if the donkey boilers are out of action.

In addition to these arrangements three air-driven, submersible, fire and salvage pumps are provided, and the ship generally carries at least four steel-built lifeboats, one each side amidships and one each side aft.

Before loading a fresh cargo the tanks must be cleaned out ; the extent of the cleaning depends on the kind of cargo last carried and the kind to be loaded ; most of it can be done at sea, but sometimes shore assistance is necessary. If the last cargo carried and that to be loaded are both of a crude nature (sometimes called " dirty " or " black " cargo), such as fuel oil, petroleum and creosote, thoroughly hosing down the tanks with sea water should suffice, but if the last cargo was of a crude nature and the cargo to be loaded is of a refined nature (sometimes called "clean"), such as benzine, naphtha, aviation spirit and lubricating oils, then more thorough cleaning is necessary. This may entail steaming the tanks, *i.e.*, shutting them down and admitting steam to them through the steam heating system, hosing them down with hot fresh water, thoroughly drying them out with cloths, and thoroughly ventilating them by means of windsails ; and very dirty tanks may have to be cleaned with steam generated from caustic soda mixed with water. Sometimes this cleaning may be supplemented at the loading port by pumping " gas oil " through the tanks and cargo lines and then thoroughly drying out the tanks.

The older tankers are mostly driven by steam reciprocating engines, or steam turbines with geared or electrical transmission, both types being provided with oil-fired boilers ; most modern tankers, however, are driven by diesel engines. The table below gives the operational particulars of some modern diesel-engined tankers.

Speed, knots ...	10	11	12	13	14	15
Deadweight, tons ...	10,000	11,000	12,000	13,000	14,000	15,000
Displacement, tons	14,000	15,470	17,000	18,400	19,800	21,400
Length, b.p. ...	428′ 0″	443′ 0″	460′ 0″	476′ 0″	492′ 0″	510′ 0″
Breadth, moulded ...	56′ 6″	59′ 3″	62′ 0″	64′ 6″	67′ 3″	70′ 0″
Depth, moulded ...	31′ 10″	32′ 11″	34′ 0″	35′ 0″	36′ 3″	37′ 0″
Draught	26′ 0″	26′ 10″	27′ 7″	28′ 4″	29′ 3″	30′ 0″
Engines, b.h.p. ...	1,900	2,650	3,600	5,000	6,800	8,800
Fuel consumption tons/day	8	11	15	21	29	37

Factors affecting the Design of Merchant Ships

Each type of merchant ship has been evolved to meet the requirements of her particular trade, and her design has had to be subjected to certain restrictions which are imposed by law to ensure the safety of the ship, her passengers and her crew.

Among the many factors affecting merchant ship design are the nature of the cargo or the type of passenger to be carried, the maximum length of run between

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fuelling ports, the speed required, dock dimensions and depth of water in the ports to be used, the conditions of climate and weather likely to be encountered, the first cost of construction, and operating costs.

In addition to meeting the owner's requirements, certain features of the construction of a merchant ship, and the extent to which she may be loaded, are subject to certain standards and restrictions which are imposed by law and by rules laid down by the Classification Societies.

It is legally compulsory for all except a few special types of merchant ship to carry permanent marks on each side of the hull indicating the maximum draughts to which the ship may be loaded in different localities at different seasons of the year. These load lines are determined by assigning in each case the minimum freeboard permissible, and this freeboard depends upon the ship's dimensions, type, and structural strength. The maximum permissible displacement of a ship, and thus the extent to which she may be loaded, is therefore limited by law.

Classification Societies, originally formed to meet the needs of marine insurance, have laid down certain rules which must be observed in the construction of ships classed with them, and it is authoritatively accepted that vessels built to the standards defined in these rules shall be considered to be capable of being safely loaded to the maximum draught prescribed. The rules specify the hull scantlings (*i.e.*, standard dimensions for parts of the structure) and therefore virtually determine the minimum weight of the hull structure.

The difference between the maximum displacement allowed and the weight of the hull structure is the weight of the machinery, equipment, bunkers, water, stores, crew, passengers and cargo, and it is the designer's problem to allocate as much as is possible of this weight to earning capacity, *i.e.*, to cargo and passenger carrying capacity.

A further factor, however, which has to be taken into account is the effect on the general design of the ship of the dues which the owners will be required to pay for the use of harbours, docks, canals, and other port facilities during the lifetime of the ship. By law all ships must be measured for " tonnage " on which such dues are levied, and it is therefore a further problem of the designer to embody in the construction of the ship all those factors which tend to reduce the tonnage measurement as much as possible.

To summarise, it may be said that in endeavouring to give the shipowner a maximum carrying capacity, the ship designer is restricted by regulations in the following ways :—

(i) By having to provide for the safety and comfort of the passengers and crew. This is dealt with by the Ministry of Transport (formerly the Board of Trade) which prescribes :—
   (*a*) the maximum draught, by the assignment of load lines ;
   (*b*) conditions regarding watertight bulkheads and their spacing, in passenger ships ;
   (*c*) the detailed design and arrangement of life-saving appliances ;
   (*d*) structural requirements for restricting the spread of fire, in passenger ships ;
   (*e*) the minimum standards for crew and passenger spaces ;
   (*f*) conditions for stowage of cargoes such as coal, grain in bulk, dangerous goods, inflammable or explosive materials or liquids, etc.

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(ii) By having to ensure the safe transport of the ship and her cargo under the normal hazards of the weather she is likely to encounter during her voyage.

To serve as a guide for insuring the ship and her cargo, vessels are usually classified according to the rules of the Classification Societies. The fact that a ship is classified is accepted by the Ministry of Transport as a guarantee that she is structurally sound and efficiently equipped for her service. If a vessel is not so classified the Ministry's surveyors make the initial survey and subsequently the periodical surveys necessary to ensure that she is maintained in a satisfactory condition.

(iii) By reducing the tonnage measurement in order to keep down harbour, dock and canal dues.

(The measurement for "tonnage" is carried out by surveyors appointed by the Ministry of Transport.)

Classification Societies

The original society for classifying merchant ships according to their strength and seaworthiness was Lloyd's Register of British and Foreign Shipping. It was formed in 1760, by persons engaged in marine insurance, as an association for protecting their interests at a time when no standards of strength and seaworthiness were laid down by law. The British Corporation, a similar but smaller body, was founded in 1890 at Glasgow by shipowners and others with marine interests, but in 1949 it was amalgamated with Lloyd's Register. There are several other Classification Societies which publish register books and rules of construction; these are mainly used in foreign countries.

Minimum freeboards, the methods by which they are assigned and corresponding standards of strength, are now laid down by law and, although legally they are administered by the Ministry of Transport, the assignment of freeboards has been delegated by the Ministry to certain Classification Societies for ships classed with them. The activities of the Societies go further and include regular, detailed surveys of hulls and machinery during the lifetime of a ship, as well as during her building, and they also include the tests of materials.

Lloyd's rules for determining the scantlings for any member of a ship's structure are in the form of a series of tables in which the scantlings are given in relation to the main dimensions of the ship, *e.g.*, her length, beam, draught and depth. These tables, being based on the Society's accumulated experience, ensure the production of a thoroughly reliable ship. A ship built to the scantlings set forth in Lloyd's rules is designated in the Register as being classed "100 A."

There are other designations for ships of special types, examples being:—"Class 100 A for Vessels Carrying Petroleum in Bulk"; "Class 100 A for Special Service Vessels," *e.g.*, tugs; "Class 100 A for Vessels in Restricted Service," *e.g.*, cross-channel packets, in which some relaxations of the normal rules for passenger-carrying vessels are permitted; and "Class A for Restricted Service Vessels" in which lighter scantlings have been specially approved by the Committee for trade in sheltered waters.

The figure '1' placed after a ship's classification character indicates that her anchors, cables and hawsers are in a good and efficient condition and in accordance with Lloyd's rules, or, if she is a special service vessel, that they are approved for that service. Vessels built under the Society's special survey

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are entitled to the distinctive mark of a Maltese cross in front of their classification character.

A steel-built vessel can only retain the classification assigned to her when she was built if she passes a special survey every four years, these surveys becoming progressively more exacting as her age increases. In addition, all vessels are subject to annual or occasional surveys when practicable.

Load Lines

With the exception of certain minor vessels, it is required by international law that all merchant ships shall comply with specified minimum requirements in regard to the height of their freeboard, in order to ensure the safety of life at sea. The freeboard for each ship is assigned according to certain rules to ensure that the ship will have a reasonable reserve of buoyancy, and it determines the maximum draught to which the ship shall be loaded. This draught is required to be marked on the ship's sides by a load line.

The methods employed in the assignment are given in a " Statutory Rule and Order " called *The Load Line Rules*, published for the Ministry of Transport by H.M. Stationery Office, which includes regulations governing the minimum standards of strength to ensure that the structure of the ship can withstand the stresses set up by the loading when she is floating at the prescribed maximum draught. Separate rules are laid down for tankers, sailing ships, and ships carrying deck loads of timber. Exceptional cases are dealt with individually.

To qualify for the minimum freeboard allowed by *The Load Line Rules*, a ship must be built to scantlings which comply with the highest standard of the rules of certain Classification Societies or which comply with standards of strength laid down in *The Load Line Rules*. Most passenger liners, however, cannot be loaded down to the maximum draught permissible for their dimensions because of the limited space available for cargo, and they would be unnecessarily strong if built to these standards. Such ships can be assigned an increased freeboard, and an allowance can be made for the lighter loading by permitting lighter scantlings in the hull structure. The smaller freeboard allowed to tankers has already been explained.

The freeboard is measured from the uppermost complete deck in which are incorporated permanent means of closing all openings in those parts of the deck exposed to the weather. In flush-decked ships, and in ships with detached poop, bridge and forecastle superstructures, this is the upper deck. In ships with a continuous non-watertight superstructure (*i.e.*, shelter-deck vessels) the freeboard is measured from the deck below the uppermost deck.

The amount of the freeboard assigned to a ship depends mainly upon her length ; the longer the ship the greater must be her freeboard. Corrections are made to the standard freeboard appropriate to the ship's length in accordance with the ship's form, the extent and height of her superstructures, any excess or lack of sheer or camber, and the ratio of her length to her depth measured from her freeboard deck.

The assigned freeboard is measured, midway between the bow and stern of the ship, vertically downwards from the upper surface of the freeboard deck where it meets the ship's side. It is indicated by a circle bisected by a horizontal line which is commonly called the " Plimsoll mark," and it is permanently marked by chisel or centre-punch on the ship's side and then painted over in white or yellow on a dark background or black on a light background. Additional

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lines known as load lines are similarly marked immediately before the assigned freeboard to indicate the minimum freeboards allowed in different seasons and localities, in fresh water, and in any other circumstances applicable to the ship, her trade or her route. Typical markings are shown in Fig. 114 and described below.

'S' indicates the summer freeboard, and this usually corresponds with the assigned freeboard.

'W' indicates the winter freeboard, which is greater than the summer freeboard by a quarter of an inch per foot of the summer draught.

'WNA' indicates the winter freeboard for voyages in the North Atlantic, and is greater than the winter freeboard by two inches for vessels not exceed-

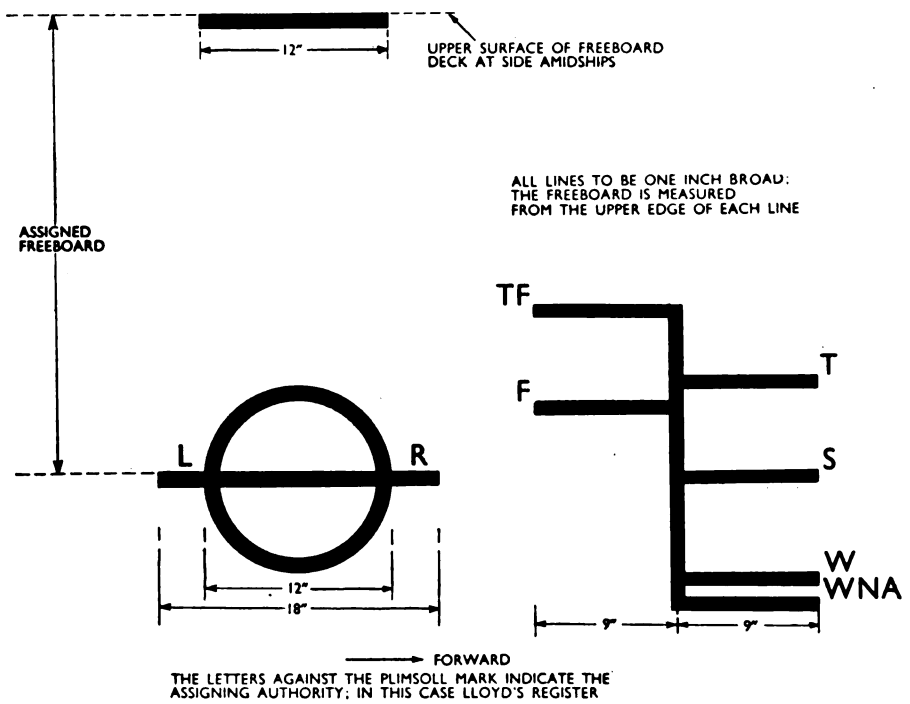

Fig. 114. Plimsoll mark and load lines

ing 330 feet in length; for vessels over 330 feet in length the WNA freeboard is the same as the winter freeboard and therefore is not indicated.

'T' indicates the tropical freeboard, and is less than the summer freeboard by a quarter of an inch per foot of the summer draught.

'F' indicates the freeboard in fresh water when loaded to the summer draught, salt water, displacement.

'TF' indicates the freeboard in fresh water when loaded to the tropical draught, salt water, displacement.

The localities and seasons to which the different freeboards apply are laid down in *The Load Line Rules*. The rules necessarily assume that any cargo or ballast is correctly stowed and distributed to ensure that the ship is seaworthy

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and has a sufficient margin of stability, and the responsibility for this rests with the master. The " Certificate of Approval " for the load lines assigned to a particular ship is issued by the Ministry of Transport or the Classification Society concerned, and it must be framed and displayed conspicuously in a public part of the ship. Before any ship puts to sea particulars of her actual draughts and freeboard immediately before sailing, together with the assigned freeboard, density of the water, fresh water allowances, etc., must be entered in the ship's official log book.

The assigned freeboard is checked annually by a surveyor of the Ministry of Transport, or the Classification Society concerned, who endorses the Certificate accordingly in the space provided. The Certificate is valid for a period not exceeding five years, and before it can be renewed the ship must be completely surveyed.

Watertight Sub-division

In addition to greatly increasing the seaworthiness of a ship by checking and limiting the inflow of any flood-water resulting from bad weather or damage, watertight sub-division provides cellular stowage for fuel, water and stores, and also a ready means of correcting any trim or list and of increasing the stability of the ship by pumping or counter-flooding.

Too much sub-division, however, limits the stowage space for cargo, hinders communication between different parts of the ship, complicates the arrangements for draining, pumping and ventilating, and increases the number of the crew required to work the ship.

No definite rules regarding sub-division were laid down for British passenger ships until 1914, when rules were formulated after the loss of the White Star liner *Titanic* in mid-Atlantic in 1912 with great loss of life after colliding with an iceberg in thick fog.

Various " Bulkhead Committees " have met since then, and the present (1954) rules are based on those formulated by the International Convention for the Safety of Life at Sea, at their meeting in London in 1948.

Certain minimum standards of watertight sub-division are made compulsory by law for passenger-carrying merchant ships, but these regulations apply only to ships carrying more than 12 passengers. The only rules governing the watertight sub-division of cargo ships are those of the Classification Societies, which specify the minimum number of bulkheads according to the length of the ship ; Lloyd's Society, for example, requires four bulkheads in ships under 285 feet in length, and lays down a scale rising to nine bulkheads for vessels between 540 and 610 feet in length. The spacing between bulkheads is not specified but must be reasonable.

The regulations for passenger ships formulated in 1948 by the International Convention provide for :—

(i) a minimum standard of watertight sub-division for various types of ships ;

(ii) the arrangement of such sub-division to ensure that the ship will remain afloat when one or more major compartments are flooded ;

(iii) a sufficient margin of stability for the safe operation of the ship ;

(iv) precautions to prevent the spread of fire.

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The standard of subdivision varies with the type of ship, and the highest degree is required in ships of the greatest length and engaged primarily in carrying passengers.

The following terms are used when fixing the maximum permissible spacing of the bulkheads in any particular passenger ship :—

the bulkhead deck is the uppermost deck to which the main transverse watertight bulkheads are carried ;

the margin line is a line parallel to, and three inches below, the bulkhead deck where it meets the ship's side ;

the floodable length at any position in a ship is the length of the longest possible watertight compartment, having its transverse centre-line at the selected point, the flooding of which would not quite submerge the margin line.

The " permissible length " is the length which determines the maximum permissible distance between watertight bulkheads. This distance is usually less than the "floodable length" by an amount which depends upon the positions of the bulkheads, the maximum number of passengers carried, and the volume of the passenger and machinery spaces. The smaller the ratio of the actual permissible length to the " floodable length " the higher is the standard of sub-division ; for example, if the ratio were one half or less, the flooding of any two adjacent compartments must not submerge the ship to her margin line, and similarly if the ratio were one third or less, the ship must survive the flooding of any three adjacent compartments.

To ensure that the provisions of these rules are carried out a passenger ship is marked with a " convention line " alongside her load lines, and when she is carrying more than 12 passengers she must not be loaded to an extent which will submerge this mark. Ships in which extra accommodation may occasionally be provided for passengers, *e.g.*, ships chartered for the pilgrim trade or as troopships, are marked with two and sometimes three of these lines to conform with the number of her passengers and the situation of their accommodation. The lines are marked C_1, C_2 or C_3 accordingly, and in British ships their positions are assigned by the Ministry of Transport's surveyors.

Very close sub-division is not necessarily an advantage because, if too close, a watertight compartment may be so short that damage may cause flooding both before and abaft it. For this reason the regulations specify a minimum spacing between bulkheads of 0·03L + 10 feet, where L is the length of the ship between perpendiculars measured at a prescribed waterline.

Longitudinal bulkheads may limit the amount of flooding and help to preserve the waterplane area, but they may also cause the ship to heel badly by confining the flood-water to one side of the ship. It is therefore specified that the angle of heel which would be caused by flooding any wing compartments consequent upon damage over a length of 0·03L + 10 feet shall not exceed seven degrees, or submerge the margin line.

Apart from the spacing of transverse and longitudinal watertight bulkheads, the effects of watertight decks, inner skins and similar structures on heel and stability are also required by regulations to be carefully examined.

Bulkheads constructed for preventing fire from spreading are required to be fitted above the bulkhead deck. They must be of steel and of equal scantlings and stiffening to those of the watertight bulkheads immediately below them, and

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they must be fire-resistant. The mean distance between any two such bulkheads must not exceed 131 feet, and the means of closing all openings in them must be fire-resisting and flame-tight. Further sub-division of these main spaces is required unless automatic fire-alarm and extinguishing systems are fitted.

Tonnage Measurement

Every merchant ship is required by law to be measured during building for the assignment of her " tonnage," and warships are also similarly measured. This tonnage forms the basis on which the appropriate dock, harbour and canal dues will be assessed, and is stated in terms of " tons " of 100 cubic feet.

Tonnage is supposed originally to have referred to the carrying capacity of a ship in " tuns " of wine, one tun having a capacity of 252 " wine " gallons and occupying about 42 cubic feet, but the present form of measurement was introduced by the Merchant Shipping Act of 1854. It is a measure of the internal volume of a ship in tons capacity, and must not be confused with " displacement " which is the actual weight of the ship in tons weight. Although merchant ships are nearly always referred to by their tonnage—gross, register or net, and deadweight—warships are invariably referred to by their displacement ; the displacement of a warship depends on her condition of loading (whether light, deep, etc.), and a figure commonly used nowadays is the " Standard Displacement," which is the weight of the ship complete when fully manned and equipped with her stores and ammunition on board, but without her fuel and reserve feed-water.

The more important terms used in connection with the tonnage of merchant ships are explained below.

The tonnage deck is the upper deck in ships having less than three decks, and the second continuous deck from the bottom in other vessels.

Tonnage length is measured along the upper surface of the tonnage deck, from the inside of the frames or sparring at the stem to a similar point right aft.

Under-deck tonnage is the volume of the ship below the tonnage deck and measured to the inside of the frames or sparring, in tons of 100 cubic feet. In British tonnage measurement double-bottom spaces are not included, the depths for tonnage being measured to the upper side of the tank-top plating or the hold ceiling.

Gross tonnage is the under-deck tonnage plus the tonnage of between-deck spaces and all permanently closed-in erections above the tonnage deck which are available for cargo, stores or accommodation.

Net or register tonnage is the figure on which harbour, dock, canal and similar dues are assessed. It is obtained by deducting from the gross tonnage certain allowances for non-earning spaces, principally the propelling machinery and steering engine compartments, water ballast tanks, cable lockers, accommodation for the officers and crew, and navigation spaces such as the wheel and chart houses.

Deadweight tonnage is the total weight of the cargo, stores, fresh water, fuel and crew which a vessel can carry when loaded down to her marks, and it is measured in tons weight.

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Full details of the regulations for the measurement of tonnage, exempt spaces, and deductions for net tonnage are given in the pamphlet *Instructions as to the Tonnage Measurement of Ships*, published for the Ministry of Transport by H.M. Stationery Office.

For comparing the sizes of merchant ships, tonnage figures are not a reliable guide owing to the variations in the exemptions and deductions allowed for differences in details of their construction. The net tonnage is particularly misleading, and so sometimes is the gross tonnage, although it gives a fair idea of the bulk of a ship. A typical example is the open shelter-deck ship, so called because practically the whole of the between-deck space under the shelter-deck is regarded in British tonnage measurement as an " open " space, owing to there being at least one non-weathertight " tonnage hatch " in it, and it is therefore exempt from measurement, *i.e.*, it is not included in the gross or net tonnage. A ship of the same dimensions without such an opening would have a considerably greater tonnage, because the exemption would not then apply.

Suez and Panama Canal Tonnage.—The principles governing the measurement of ships by the Suez or Panama Canal rules are the same as for British tonnage, but there are detailed differences as regards the exemption of certain spaces and the deductions allowed for net tonnage. These tonnage figures often vary considerably from the British Register Tonnages.

Tonnage of Warships.—All H.M. ships are measured by the Ministry of Transport for tonnage in accordance with both the British and Suez Canal rules, a copy of the tonnage certificate being kept on board in the *Ship's Book*. An important difference between warships and merchant ships is that no deduction for crew spaces is allowed in the net tonnage of the former. By agreement between the Admiralty and the tonnage assigning authority and the harbour authorities, the dues to be paid by the Admiralty for the use of British docks and harbours by H.M. ships are based on the legal net tonnage, reduced by seven per cent of the gross tonnage to allow for crew spaces. This " special " tonnage figure is inserted on a slip attached to the tonnage certificate.

In the Suez Canal a crew and navigation space deduction, limited to five per cent. of the gross tonnage, is allowed to warships. Double-bottom spaces are not included in the tonnage but must be paid for in passing through the canal if they contain more than six inches depth of oil fuel ; they are then paid for on their full capacity.

In the Panama Canal, warships are assessed on their actual displacement. Curves of displacement and tons per inch immersion are included with the Statement of Stability kept in the *Ship's Book*.

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CHAPTER XVIII

Ship Stability

THE PRINCIPLES which determine the stability of a ship were outlined in Chapter XIV of Volume II of this manual. In this chapter ship stability is dealt with more comprehensively in order to show how a fuller knowledge of its principles can be used to determine the degree of stability of a particular ship at any condition of loading, and also the measures which should be taken to re-establish the stability of a ship which has been flooded as a result of underwater damage.

TRANSVERSE STABILITY

Righting Moment

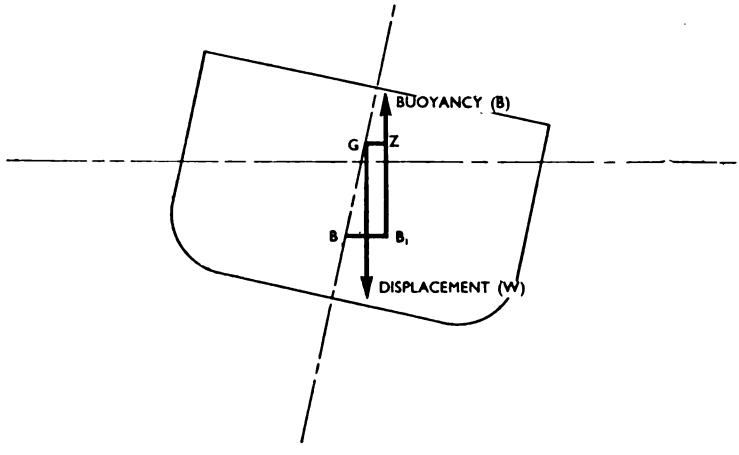

Fig. 115. Righting moment

In Chapter XIV of Volume II of this manual it was shown that :—

(i) the position of the centre of gravity (G) of a particular ship will vary with her condition of loading ;

(ii) the position of the centre of gravity for any particular condition of loading will remain fixed, apart from a slight movement due to free-surface liquids, during any movement of the ship, and it will lie somewhere on the middle line plane of the ship if she is symmetrically loaded ;

(iii) the position of the centre of buoyancy (B) will lie directly below the centre of gravity when the ship is steady, but when the ship heels it will move to a position (B_1) in the centre of the submerged volume of the ship ;

(iv) the forces of weight and buoyancy are each equal to the displacement of the ship (W), and they act vertically in opposite directions ;

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(v) the force of buoyancy acting upwards through B_1 when the ship is heeled will produce a moment tending to right the ship, and this moment is calculated by multiplying the displacement (W) by the righting lever (GZ), this being the horizontal distance between the forces of weight and buoyancy ;

(vi) the righting moment depends chiefly on the angle of heel and the movement of the centre of buoyancy ; it will increase with an increase of the angle of heel up to a certain critical angle, but thereafter it will decrease with any further increase of the angle of heel, and will eventually change to a capsizing moment.

Transverse Metacentre and Transverse Metacentric Height

In most ships, for small angles of heel of up to about 10 degrees, the line of action of the force of buoyancy (B_1) will cut the middle line of the ship at a fixed point (M) which is called the " transverse metacentre." (See Fig. 116.)

The height of the metacentre (M) above the centre of gravity (G) is called the " metacentric height," and it gives a measure of the initial stability of the ship, *i.e.*, her stability at small angles of heel.

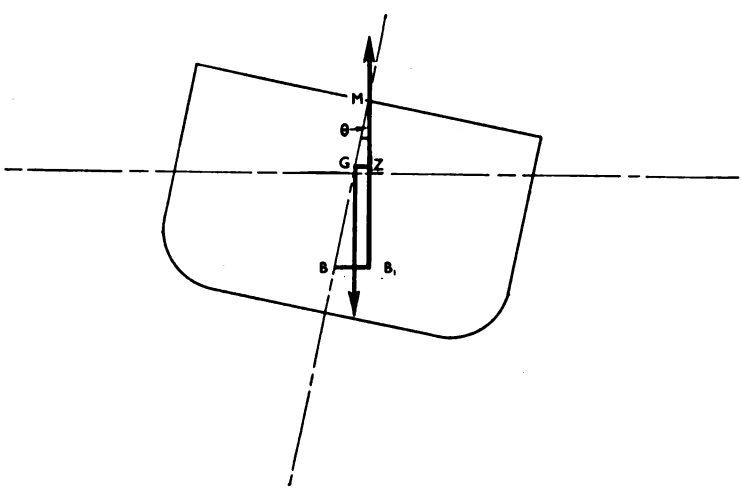

Fig. 116. Transverse metacentre and metacentric height

Considering the triangle GMZ in Fig. 116 the angle θ at its apex is equal to the angle of heel, and the righting lever (GZ) will be equal to GM sin θ. If the metacentric height (GM) is known, the righting moment can be found by multiplying the righting lever (GZ) by the displacement of the ship (W).

When a ship is heeled, the position of her transverse metacentre depends upon the shape of her waterplane and on the position of the centre of buoyancy (B_1), which in turn depends on the draught of the ship and the underwater shape of her hull. At angles of heel of over say 10 degrees the position of the transverse metacentre will not be fixed but will change with the angle of heel, and the designer must arrange the dimensions of the hull to ensure not only a reasonable margin of initial stability at all normal conditions of loading, but also a reasonable margin of stability over the probable angles of heel to which the ship may roll in a heavy sea. In general it can be assumed that if a ship is of normal form and has a reasonable margin of initial stability at all normal conditions of

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loading she will also have sufficient stability to right herself from any angle to which she may be heeled in the normal course of events.

Position of the Transverse Metacentre

The height of the transverse metacentre above the centre of buoyancy (BM in Fig. 116) depends solely on the form of the ship at and below her waterline, and it will therefore vary with the beam of the ship, her waterplane area, her coefficient of fineness, and her draught. This is shown by the formula :—

$$BM\ \frac{I}{V} = k\frac{LB^3}{LBD} = k\frac{B^2}{D},$$

where :—

k is a constant depending upon the underwater form of the ship ;

L, B and D are the length, beam and draught, respectively, of the ship ;

I is the transverse moment of inertia of the waterplane area about the middle line of the ship ; and

V is the volume of the ship's displacement.

It will therefore be seen that the distance BM is directly proportional to the square of the beam, and inversely proportional to the draught.

The position of the metacentre is determined by the designer when he plans the ship, and as soon as the lines of her design are settled he constructs a " metacentric diagram " which shows the position of the metacentre for any draught at which the ship is likely to be. The method of constructing and interpreting such a diagram is described below and illustrated in Fig. 117.

Through the point L at the top right-hand corner of the figure a vertical line LK and a horizontal line LL are drawn. LK represents to a suitable scale the designed maximum draught of the ship in feet, and LL represents her designed deep-load waterline. Below LL are drawn other lines L_1L_1, L_2L_2, L_3L_3 and L_4L_4 at equal distances apart to represent other waterlines used in the calculation. Through K a horizontal line KK is drawn to represent the level of the keel of the ship. Next the diagonal LK is drawn so that it bisects the right-angle at L formed by the lines LL and LK. Vertical lines K_1, K_2, K_3, K_4 and K_5 are drawn through the intersections of the diagonal line with the horizontal waterlines.

The vertical distance of the centre of buoyancy below each of the waterlines and the distance of the corresponding metacentre above each waterline having been calculated, these distances are now plotted above and below their respective waterlines, producing the points B, B_1, B_2, B_3, B_4 and B_5, and M, M_1, M_2, M_3, M_4 and M_5. Curves are then drawn through these points, and these will represent the curves of buoyancy and metacentres.

This diagram shows at a glance the height of the transverse metacentre above its corresponding centre of buoyancy, and above the keel, for each of the various waterlines. From it, also, the height of the metacentre above the centre of buoyancy and the keel for any mean draught can readily be obtained by drawing a horizontal line at the given mean draught and drawing a vertical line through the point where it cuts the diagonal line LK ; the point where the vertical line cuts the curve of metacentres is the metacentre for that particular mean draught.

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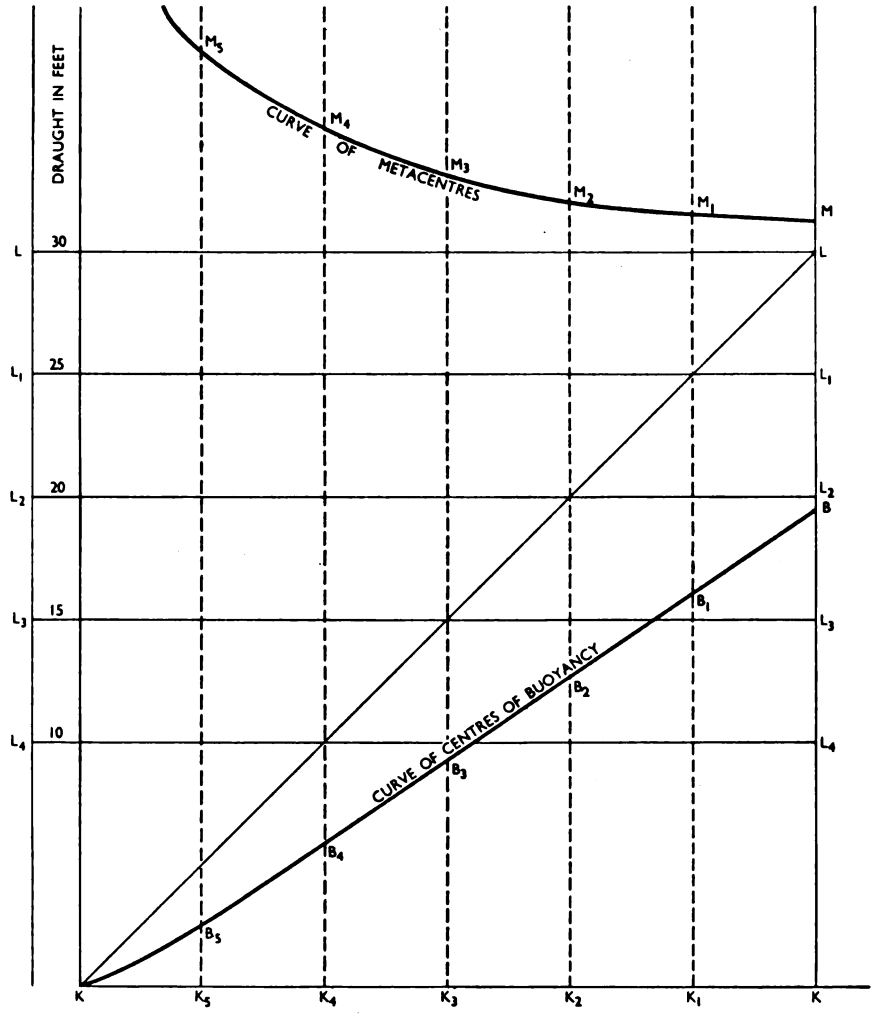

Fig. 117. Curves of metacentres and centres of buoyancy

Degree of Transverse Stability

The degree of initial stability, as measured by the ship's transverse metacentric height at any particular condition of loading, depends on the relative positions of her transverse metacentre and her centre of gravity. The position of the transverse metacentre is determined by the designer and so cannot be altered by the seaman ; it depends entirely on the underwater shape of the hull and it will change only as the draught of the ship changes. The centre of gravity, however, depends largely on the disposition of the fuel, water, stores and any cargo or ballast which the ship may be carrying, and it can therefore be altered by the seaman to provide the necessary margin of initial stability.

A ship with a large transverse metacentric height has a high resistance to rolling forces, and so will roll with a short, rapid motion ; such a ship is said

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to be " stiff." A ship with a small transverse metacentric height does not offer so much resistance to rolling, and so will roll with a long, slow motion; such a ship is said to be " tender."

A ship's degree of stability, as measured by her transverse metacentric height, should not, however, be taken as a measure of her seaworthiness. A ship that is too stiff can be just as dangerous as one that is too tender, because rolling that is too rapid and violent may shift her cargo, carry away her masts, strain her hull and even unseat her machinery.

The degree of transverse stability should therefore be arranged to suit a ship's characteristics, and the duties or trade on which she is engaged. Passenger liners must not be too stiff or the comfort of their passengers will suffer, nor should cargo vessels be too stiff or their cargo may shift when they are in a seaway. Warships, on the other hand, must usually be stiffer than merchant ships to ensure a reasonable margin of stability should they be flooded from underwater damage, but they must not be too stiff or the accuracy of their gunfire may be impaired by too violent rolling. The stability of vessels intended for fixed routes, such as cross-channel packets, ocean liners, and vessels sailing on inland waterways, is often designed to suit the kind of seas they will probably encounter, and this should be borne in mind if it is intended to use such vessels where the usual sea conditions are very different from those for which they were designed.

Stability at Large Angles of Inclination

The simple expression for the length of the stability lever given on p. 397, *viz.*, $GZ = GM \sin \theta$, applies only to small angles of inclination of up to about 10 degrees for ships of normal shape. At greater angles the line of action of the force of buoyancy does not pass through a fixed point as it does for lesser angles.

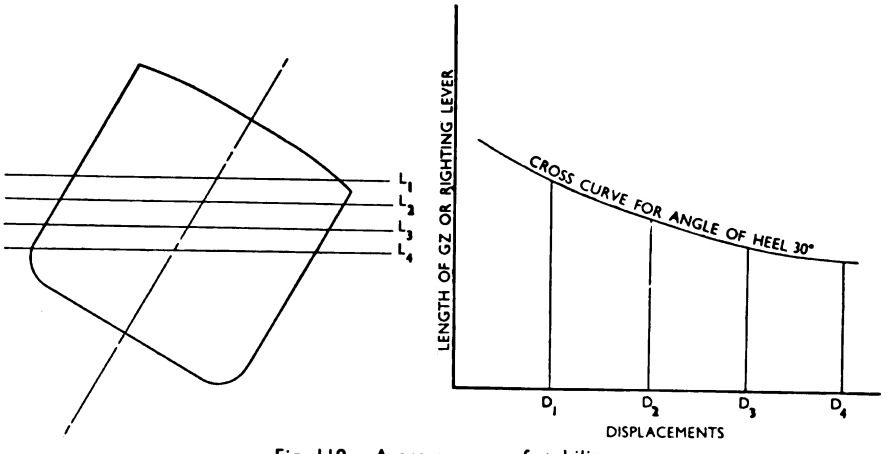

Fig. 118. A cross curve of stability

By means of a series of involved calculations, however, the designer can estimate the length of the stability lever at various angles of heel at different displacements, and he can then describe them graphically. For this purpose the centre of gravity of the ship is assumed to be at a certain fixed position, and the righting lever at various angles of heel is calculated for four selected dis-

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placements (see Fig. 118). These four displacements are set off to scale along a horizontal base line, and at each of them the length of the stability lever corresponding to a particular angle of heel is set up to scale from the base line, and through the four points thus obtained a fair curve is drawn. This curve is called a " cross curve of stability " and six of them are usually drawn, *i.e.*, for angles of inclination of 15, 30, 45, 60, 75 and 90 degrees. From these curves combined cross curves of stability can be drawn on a single graph to show the length of the righting lever at various displacements for each of the six angles of inclination (see Fig. 119).

From this graph " curves of statical stability," sometimes known as " righting lever " or " GZ " curves, can be drawn for specified conditions of loading. These curves give the length of the righting lever (GZ) for various angles of heel, and each shows graphically the degree of stability of the ship in the condition for which the curve was drawn.

A typical stability curve is shown in Fig. 120 and its general features are described below.

(i) At small angles of heel (up to about 10 degrees) the curve is approximately a straight line, and the angle which it makes with the base line is governed by the metacentric height since $GZ = GM \sin \theta$ when θ is small.

(ii) As the angle of heel increases above 10 degrees the steepness of the curve increases, and it is steepest at the angle at which the freeboard deck-edge becomes immersed.

(iii) As the angle of heel increases still further the steepness of the curve decreases, until it becomes horizontal at an angle of heel called the " angle of maximum righting lever."

(iv) Thereafter the curve descends, at first with increasing steepness and then at a steady angle of descent, until it crosses the base line at a point called the " vanishing angle," at which there is no righting lever and beyond which a capsizing lever is set up. This point defines the limit of the " range of stability " of the ship for that particular condition of loading, and it is sometimes called the " range."

The angle of maximum righting moment is the largest angle of *steady heel* which a ship can take up without capsizing when inclined by a constant heeling moment, because under these conditions the righting moment must balance the heeling moment. These conditions are only theoretical, however, because it is assumed that the sea is calm and there is no wind. Actually, when a ship is inclined to her angle of maximum stability by a steady heeling force, set up by a wind or asymmetrical flooding, for example, a slight increase in the force or a slight movement of the ship may cause her to capsize. The angle of maximum righting moment must not therefore be regarded as an angle at which the ship is safe under the influence of a steady heeling force ; it represents, in still water, the angle at which the ship has no further margin of stability against capsizing.

Rolling

The " period of roll " of a ship is the time she takes to move from her extreme angle of a roll on one side to her extreme angle of a roll on the other and then back again to the extreme angle from which she started. The period depends on the degree of transverse stability of the ship in any one condition of loading and also upon the disposition of weights about her longitudinal centre-line, but for any one condition the period of roll of a ship within small

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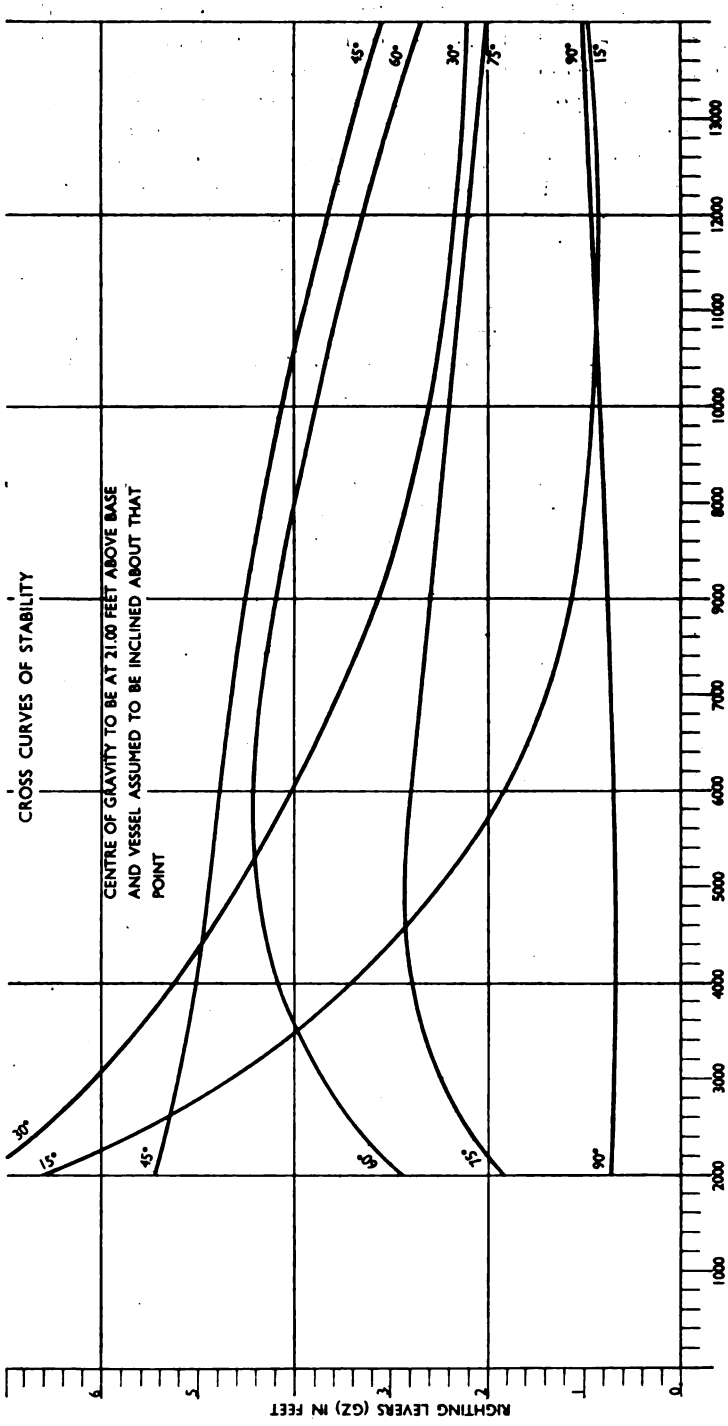

Fig. 119. Typical example of combined cross curves of stability

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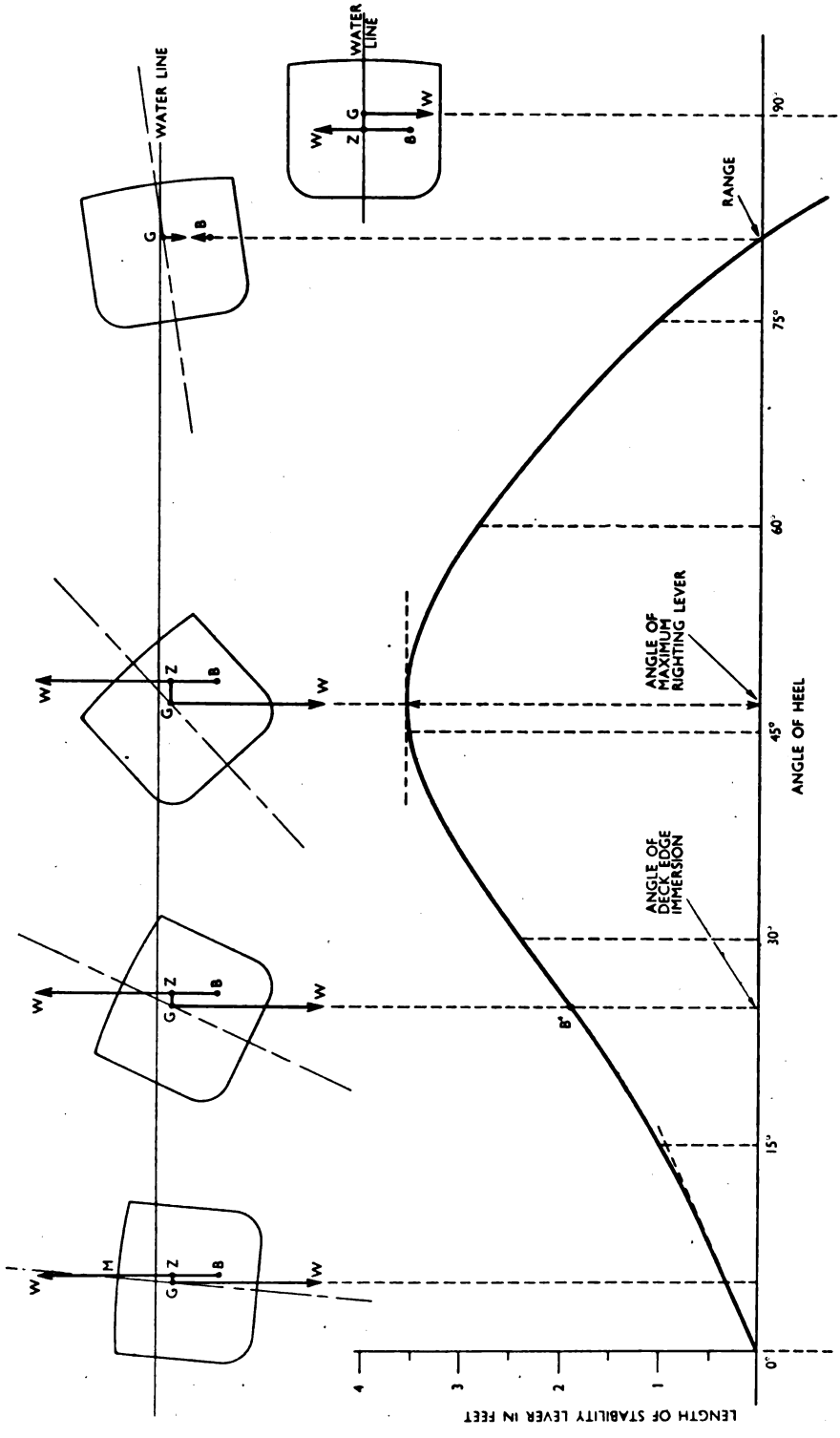

Fig. 120. Righting lever or G.Z. curves

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angles, of, say, from 10 to 15 degrees each side will be the same irrespective of the angles to which she rolls ; in other words her periods for rolls of say 10 degrees and 5 degrees will be the same for any one condition of loading. For large angles of roll the period increases with the angle of roll because of the change of metacentric height at large angles of heel. For ease of description it is best to deal first with the imaginary case of a ship rolling unresistedly in still water, then to pass to the case of a ship rolling with resistance in still water, and finally to deal with rolling in a seaway.

Unresisted Rolling

If a ship in still water is inclined to one side by some exterior force which is then suddenly removed, her moment of transverse stability will return her to an upright position and the momentum thus gained will then roll her to the other side. The moment of stability will then progressively retard the ship's momentum and eventually bring her momentarily to rest at the same angle of heel as that to which she was originally inclined. The moment of stability will then return her again to an upright position and her momentum will carry her back again to her original angle of heel. If there were no resistance to rolling this movement from side to side would continue indefinitely.

The greater the moment of stability the quicker will the ship regain an upright position after being inclined, and therefore a stiff ship will have a shorter period of roll than a tender one.

The degree of stability of a ship, however, does not entirely govern her period of roll, because this is also affected by the disposition of weights within the hull. If two ships of the same displacement and with similar transverse metacentric heights are inclined to the same small angle, their moments of stability will be the same, but if the weights in one ship are " winged," *i.e.*, placed at the sides as far from her fore and aft centre-line as possible, and in the other they are concentrated close to the centre-line, then the former ship will have a greater period of roll than the latter. This is owing to the difference between the moments of inertia of the weights about the axis of roll, which, broadly speaking, increase with the square of their distance from that axis. In practice this fact is used to advantage by ships carrying heavy bulk cargoes, such as manganese ore, in order to give them a long, easy motion in a seaway and to guard against their cargo shifting because of violent rolling.

Resisted Rolling in Still Water

The resistance offered by the water to the rolling of a ship can be categorised under the following three headings :—

" frictional resistance " between the particles of water and the hull surface ;

" eddy resistance " caused by flat or projecting surfaces of the hull, such as the rudder, the forward and after deadwoods, and the bilge keels ; and

" surface disturbance " caused by the displacement of the water close to the ship by the movement of her hull from side to side.

Of these the frictional resistance is so small that it can be disregarded. Resistance due to surface disturbance is the greatest, and its effect is to increase the natural moment of inertia of a ship by about 20 per cent. The effect of eddy resistance is about one fifth of that of surface disturbance, and its effect is greater when the ship has way on her than when she is stopped.

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The resistance of the water will therefore progressively reduce the rolling of a ship, and the more violently she rolls the greater will be the resistance. A ship which has been set rolling in still water will therefore eventually be brought to rest in a period depending largely upon her degree of stability and her period of roll.

In general the resistance of the water tends not only to reduce the roll of a ship but it also tends to increase her natural moment of inertia and so increase her period of roll. Its effect is greater when a ship has way on than when she is stopped, and it increases with an increase of the ship's speed.

Rolling in a Seaway

When a ship is steaming across a sea the amount her hull is immersed will be changing continually as each wave passes beneath her, and her centre of buoyancy will consequently be moving from one side to the other. Her centre of gravity, however, will remain fixed (except for a slight movement due to free-surface liquids in her), and the ship will therefore be subjected to a varying moment causing her to roll. The resultant rolling and its period will depend to a great extent on the ratio between the period of roll of the ship in still water (T) and the period of the waves (T_1, *i.e.*, the interval of time between the passing of two successive waves).

In the following examples describing a ship's reaction to a seaway it is assumed that she is steaming broadside on to the waves and that her beam is considerably less than the length of the waves.

(i) If the ratio of T to T_1 is small (as with small craft or with shallow-draught, flat-bottomed vessels with a relatively large GM, such as landing craft) any alteration in the slope of the water surface will produce a large moment in the vessel tending to roll her to a position with her masts at right angles with the surface of the wave. The vessel will then roll with the waves like a raft, but in addition she will occasionally roll rapidly about an axis at right angles to the wave surface.

Such conditions will seldom apply to ocean-going ships because wave periods are generally less than 10 seconds, and the ratio of T to T_1 will therefore seldom be small for such vessels.

(ii) If the ratio $\frac{T}{T_1} = 1$ the ship will roll heavily because the action is accumulative, the angle of roll increasing with the passing of each successive wave. Theoretically, this synchronisation of the period of the waves with the period of the ship's roll would result in the ship capsizing, but actually she does not do so because the resistance to her rolling becomes relatively greater as the angle of roll increases, and her period of roll increases with the angle at large angles of roll, so that the relation $\frac{T}{T_1} = 1$ no longer holds good.

This situation can, however, be dangerous, particularly in ships with a small transverse metacentric height, and if the ship rolls excessively and appears reluctant to recover at the extremity of a roll her course should at once be altered to break the synchronisation between the waves and the period of roll.

(iii) Lastly, if the ratio $\frac{T}{T_1}$ is large, the ship will roll with the same period as

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in still water. In this case, T being large, the transverse metacentric height will be small, and therefore a very large alteration in the wave slope will be required to produce any appreciable moment of stability in the ship, and by the time the ship has started to roll the wave will have passed on.

In these conditions the ship will probably roll only slightly and with the same period as when in still water. Such a ship is said to be " steady," and as this is a desirable quality for passenger ships they are often designed to have small transverse metacentric heights and long periods of roll. Such ships will roll independently of the waves, which will probably break against their sides, but without much inconvenience owing to the usually high freeboard of passenger liners.

Inclining Experiment

When a ship is built, or has undergone considerable reconstruction, an " inclining experiment " is carried out to determine whether the actual position of her centre of gravity for a specified condition of loading coincides with the designer's calculated position. When the actual position of the centre of gravity for one condition of loading has been determined by experiment it is a comparatively simple matter accurately to calculate its position for any other condition of loading.

The inclining experiment is usually carried out with the ship's feed water tanks, fresh water tanks, ballast tanks, fuel tanks or bunkers either empty or full and pressed up, and with her stores on board but without any ammunition or cargo. The experiment is conducted in still water, preferably in a dock or basin, and on a calm day. If there is any wind the ship should be placed head to wind. All her machinery is stopped, her pumping systems are drained and the bilges cleared, and, with the exception of those men required for the experiment, her crew are landed.

Long pendulums, about 15 ft. in length, are rigged through suitable hatchways or in the holds, usually one forward and one aft, to measure the angle of inclination, and a known weight of ballast, sufficient to incline the ship two to three degrees is placed on the upper deck and symmetrically disposed about the fore and aft centre-line. The ship should then be floating absolutely upright.

The weights are then shifted a measured distance across the upper deck, and when the ship is at a steady angle of heel her inclination is measured by means of the pendulums. The weights are then brought back to their original positions, and the ship should then regain her upright position. The weights are then shifted to the same distance from the ship's centre-line on her opposite side, and her angle of inclination to that side is measured.

The displacement of the ship is obtained by comparing the mean of her draughts forward and aft with her displacement curve, and from this information the metacentric height (GM) can be calculated from the formula :—

$$GM = \frac{w \times d}{W \times \tan \theta},$$

where :—

w is the sum of the known weights ;

d is the distance they have been moved across the ship ;

W is the displacement of the ship, including the weight of ballast (w) ; and

θ is the mean angle of inclination.

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The distance of the metacentre above the keel for this particular condition of loading is obtained from the metacentric diagram, and so the exact position of the centre of gravity can be determined.

Remarks on Transverse Stability

The transverse stability of a ship can be improved structurally by increasing the ratio of her beam to her draught, which will result in raising the position of her metacentre and thus increasing her metacentric height. A ship's stability at large angles of heel can be improved by increasing her freeboard, provided that the additional structure does not unduly raise her centre of gravity and so reduce her metacentric height. Transverse stability can also be improved by adding ballast low down in the ship or by removing topweight from her; both methods will result in lowering her centre of gravity and so increasing her metacentric height, but whereas the former will increase her draught and reduce her freeboard, the latter will have the opposite effect. Free-surface liquid, that is liquid which is free to move from side to side of a partially filled tank or compartment, will result in reducing the metacentric height.

BALLASTING AND THE REMOVAL OF TOPWEIGHT (Fig. 121)

Many cargo vessels are very tender in the light load condition, or "flying light," as it is termed, and some may then even have a negative metacentric height. To offset this tenderness they may carry "dead" ballast in the form of shingle or pig-iron at the bottoms of their holds, or they may be provided with specially constructed, rapidly floodable, ballast tanks built into their double bottoms.

The dead ballast may be carried temporarily or permanently, and in some ships both water and dead ballast are used.

The effect of ballasting is to lower the centre of gravity without materially affecting the position of the metacentre, thus increasing the metacentric height. The amount by which the centre of gravity is lowered is given by the formula $\frac{w \times h}{W + w}$, where w is the weight of the ballast, h is its distance below the original centre of gravity, and W is the original displacement of the ship. Another effect of ballasting, which may be disadvantageous, is to increase the draught of the ship.

Removal of topweight, like ballasting, lowers the centre of gravity, but as it also decreases the draught of the ship it may be preferable to ballasting in ships in which an increase of draught would be a disadvantage. The amount by which the centre of gravity is lowered by the removal of topweight is given by the formula $\frac{w \times h}{W - w}$, where w is the topweight, h is its height above the original centre of gravity, and W is the original displacement of the ship.

It is a common mistake to suppose that a ship is made "steady" by ballasting or the removal of topweight. "Steadiness" is obtained by having a small metacentric height; the metacentric height is increased by ballasting or removing topweight and the ship is made stiffer and therefore more lively. In this connection it is of interest to recall that in the last century many of the old 64-gun ships were converted to 38-gun frigates (or "razées" as they were then called) by removing the upper deck together with its guns and topsides and fitting lighter masts and yards. The removal of this topweight considerably

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increased the metacentric height, and the ships rolled so violently that they often sprang their topmasts. This failing was overcome to a certain extent by increasing the size, and therefore the weight, of the masts and yards, thus decreasing the metacentric height by adding topweight.

An opposite effect to that of ballasting arises from the consumption of fuel, water and stores if they are stowed below the ship's centre of gravity. This is

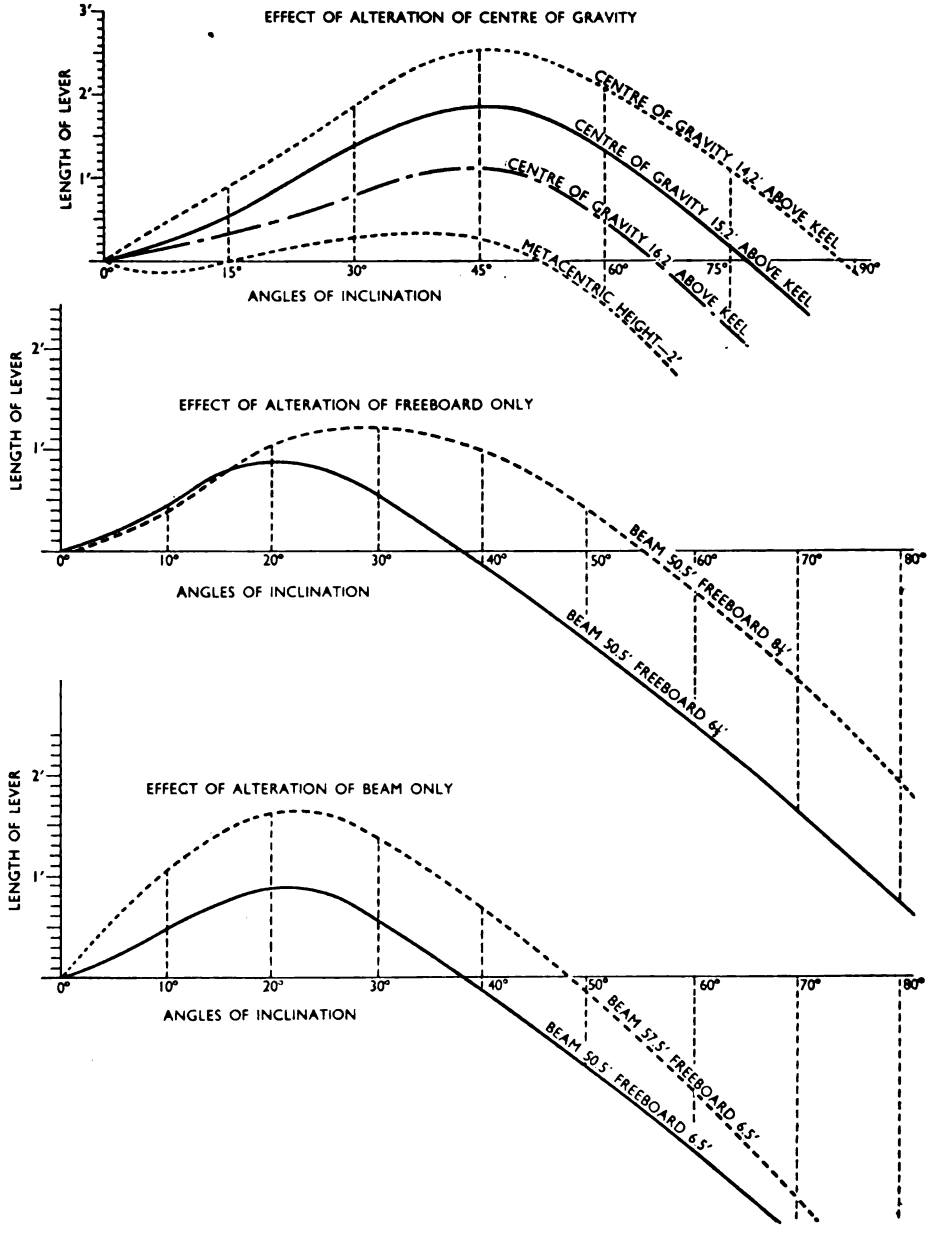

Fig. 121. Curves of stability, showing effect of altering centre of gravity, beam and freeboard

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particularly evident in the case of oil fuel, because the fuel tanks of most oil-burning ships are built into their double bottoms, and the effect of using up the oil fuel is then the same as that of removing ballast. Consuming much of the ship's fuel can seriously reduce her margin of stability unless it is countered by ballasting, or anticipated by the disposition of the cargo. In the early years of this century a cargo vessel was provided with little information about her stability, her loading being left to the judgment and experience of her master; this lack of information sometimes led to dangerous situations in which a ship, though perfectly stable on sailing was in a precarious state on arrival at her destination because of her loss of stability through the consumption of fuel and water during the voyage. Notable examples were the Baltic traders when carrying deck cargoes of timber, which often arrived in this country with negative stability and an alarming heel.

When a cargo ship is lightly laden her waterplane area may be reduced considerably by a small reduction of draught and consequently the position of her metacentre may then be lowered appreciably. When lightly laden the adverse effect of this lowering of the metacentric height must be considered in conjunction with the adverse effect of the rise of the centre of gravity due to the consumption of fuel. In a typical cargo vessel of some 10,000 tons, her centre of gravity may rise as much as six inches during a voyage while her metacentre may fall by two inches, making a total reduction of some eight inches in her metacentric height.

Increasing the Freeboard (Fig. 121)

The weight of the structure involved by increasing the freeboard of a ship will result in raising her centre of gravity, and because her draught and displacement will be increased by a small amount her metacentre will be lowered slightly. The immediate result will therefore be to decrease slightly her metacentric height and therefore her initial stability, but at large angles of heel the result will be to increase her righting moment, the angle of her deck-edge immersion, and her range of stability.

Girdling (See Fig. 121)

Though not resorted to nowadays, girdling is mentioned here because it illustrates a method of altering a ship's metacentric height by increasing her beam.

In the days of sail one of the chief tactical considerations in an action was to gain the weather gauge, so that the final approach to the enemy could be made from windward and his freedom of manœuvre thereby restricted. This necessitated fighting the lee guns, and ships of the line had to be stiff enough to resist being heeled by a beam wind sufficiently to submerge the ports of their lowest tier of guns. Moreover, the maximum angle of elevation of these guns was only 12 degrees and therefore, with her crew manning the guns on the lee side, the heel of the ship to leeward had to be limited to 12 degrees. In practice the designers of those days limited the heel to seven degrees in a " topsail wind," which corresponded to a wind pressure of 2 lb. per square foot.

Towards the end of the 17th century the stability of ships of the line was unfavourably criticised by our seamen, and our ship designers were then faced with a difficult problem, because removal of topweight would impair the ship's fighting efficiency, and ballasting would increase her draught and reduce the

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freeboard of her lower gun-ports. In the event they resorted to "girdling," which consisted of fitting a wooden belt, from 12 to 18 inches thick, around the ship at her waterline and extending three or four feet above and below it. This virtually increased the beam of the ship and so raised the position of her metacentre without materially altering her draught or the position of her centre of gravity. The rise of the metacentre was roughly equivalent to the thickness of the girdling, or half the increase of beam. An added advantage of the girdling was that it provided what was virtually an armour belt at that most vulnerable part of the ship—"between wind and water."

Effect of Free-surface Liquids

When a tank is "slack," *i.e.*, when it is not absolutely full or "pressed up," and also when it is not absolutely empty, the metacentric height is reduced by an amount depending solely on the extent of the free-surface of the liquid and its density relative to that of sea water. A few inches of liquid in the bottom of a rectangular tank would therefore reduce the metacentric height by as much as would several feet, and it is therefore important to ensure that ballast tanks are either pressed up or completely drained.

The loss of metacentric height due to free-surface is given by the formula $\frac{D\,i}{V}$, where D is the relative density of the liquid compared with the water in which the ship is floating, i is the moment of inertia of the free-surface about the longitudinal axis through its centriod, and V is the volume of displacement of the ship. The moment of inertia of the free-surface of a liquid in a rectangular tank is given by the formula $\frac{L \times B^3}{12}$, where L and B are the length and breadth respectively of the tank.

It will therefore be seen that if a tank is divided by a longitudinal partition into two equal parts the loss of metacentric height due to free-surface effect will be reduced to a quarter of that of the undivided tank. The deep tanks of cargo ships, and any large tanks which extend athwartships, are therefore divided by one or more longitudinal partitions or baffle-plates.

Pressing up a tank or completely draining it will therefore make a ship more stable but it must be emphasised here that any attempt to improve a ship's stability while at sea must be done with great caution. Pumping, flooding and draining operations take some time to carry out, and in the process the free-surface effects of the slack tanks may well cancel a margin of stability, particularly if it is small and the tanks are large. Many losses of ships have been attributed to attempts to improve their stability by pumping, flooding or draining while the ship was in a seaway.

A certain amount of ullage has to be left in fuel tanks when filling them, to allow for the expansion of the oil with any rise in its temperature, and in oil tankers this results in a considerable reduction of the metacentric height due to free-surface effects, even though the ships are designed with a high degree of compartmentation and each tank is usually divided into three parts by longitudinal bulkheads. To compensate for this adverse effect tankers are provided with a considerable margin of stability by giving them a larger ratio of beam to draught than is usually given to vessels designed for carrying a general cargo.

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Another danger is that of free water on the decks, particularly in cargo vessels of the three-island type whose forward and after well-decks are enclosed by high bulwarks. Such ships are fitted with large " freeing ports " to allow any water shipped in a seaway to drain quickly over the sides. If this were not done the effect of the free-surface water combined with the loss of metacentric height due to the added weight of the water at so high a level might seriously reduce the ship's margin of stability. Unfortunately, a ship may also ship water through her freeing ports, and it is not unknown for the flaps of the freeing ports to be secured for the sake of comfort, thus endangering the vessel should she ship a very heavy sea.

Bulk Cargoes

A bulk cargo, such as grain, can produce an effect similar to that of free-surface liquids but modified by the friction between the individual particles and their inertia; for example, a heavy roll to one side may shift the cargo, but it will not necessarily shift back with a roll to the opposite side. Bulk cargo ships are therefore fitted with permanent, or temporary, centre-line bulkheads in their holds, and these may be supplemented by " shifting boards " further to subdivide the cargo and prevent it from shifting. In addition, the cargo is pressed up to the tops of the holds and between the deck head beams, special feeder-trunks being provided over each hold for this purpose. When a hold cannot be pressed up because of lack of grain, a certain proportion of the grain must be bagged and laid on platforms over the bulk grain; the bagged grain will have little tendency to shift and by its weight will tend to prevent the bulk grain shifting.

Ships built for carrying bulk cargoes are usually designed with a higher margin of stability than those designed for carrying general cargoes, for the following reason. The centre of gravity of a bulk cargo is unalterable and lies at the centre of its volume, and when the ship is fully loaded she will therefore have a high centre of gravity; with a general cargo the position of the ship's centre of gravity can be kept reasonably low by stowing the heavier kinds of cargo in the lower holds.

Angle of Heel when Hoisting Out a Heavy Weight

The angle to which a ship will be heeled when hoisting out a heavy weight by one of her derricks is given by the formula :—

$$\tan \theta = \frac{w \times d}{W \times GM},$$

where :—

θ is the angle of heel;

w is the weight in tons to be hoisted out;

d is the horizontal distance in feet between the stowage position of the weight and its position when slung outboard from the derrick head;

W is the displacement of the ship; and

GM is her metacentric height in feet.

When hoisting a heavy weight in or out by a derrick great care must be taken to ensure that the ship has a sufficient margin of initial stability, because as soon as the weight is slung its effect will act through the head of the derrick, thus increasing considerably the height of the centre of gravity of the ship and reducing her metacentric height correspondingly. Moreover, when the weight is slung outboard, the further the ship heels the greater will be the heeling

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moment of the weight, and measures must therefore be taken to ensure that the ship remains as upright as possible throughout the operation. Ships which may have to deal with heavy lifts are provided with special ballasting arrangements to ensure the necessary degree of stability and resistance to heeling when hoisting the weights in and out, and care is taken to work the derrick slowly, and as smoothly and steadily as possible.

LONGITUDINAL STABILITY, AND TRIM

Longitudinal Metacentre

The longitudinal metacentre (M_L) of a ship is found in a similar manner to that in which her transverse metacentre is found. In Fig. 122 the ship is assumed to have been tipped forward by some external force so that the longitudinal centre of buoyancy (LCB) has moved forward to B_1, thus producing a longitudinal righting moment, W × GZ.

The height of the longitudinal metacentre above the centre of buoyancy of a ship is given very roughly by the formula $BM = \frac{L^2}{12D}$, where L is the length of the ship and D her draught. It will therefore be seen that a ship is far stiffer longitudinally than transversely.

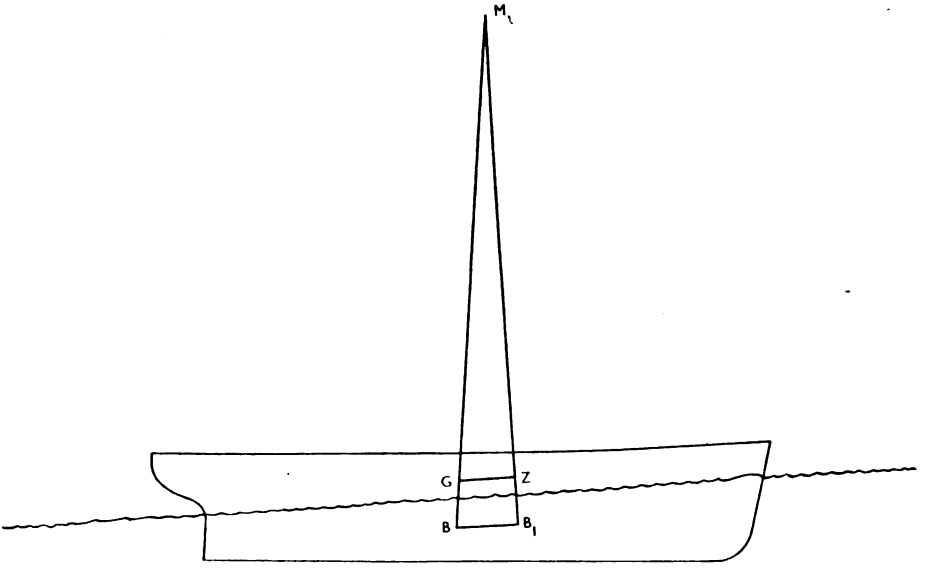

Fig. 122. Longitudinal metacentre

Longitudinal Centres of Buoyancy and Gravity

When a ship is steady her longitudinal centre of buoyancy (LCB) will lie at a position a little before or abaft amidships, and its position will change as the draught of the ship is changed. Under the same condition a ship's longitudinal centre of gravity (LCG) lies directly above her longitudinal centre of buoyancy.

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Centre of Flotation (CF), or Tipping Centre (TC)

When a ship is steady her centre of flotation, or tipping centre, lies at the centre of her waterplane area, and it is about a transverse axis through this point that the ship trims. If a weight is added to a ship directly above her centre of flotation she will sink bodily and on an even keel, but if added before or abaft her centre of flotation the ship will trim by the head or the stern, respectively, as well as sink bodily. Like the longitudinal centre of buoyancy, a ship's centre of flotation lies at a position a little before or abaft amidships, and its position will change as the draught of the ship is changed. As the draught of a ship is increased her longitudinal centre of buoyancy and her centre of flotation will usually move aft, the latter more so than the former. Both will also change position with any change of trim because this will change the waterplane area.

Tons per Inch Immersion (TPI)

This is the weight required to increase the mean draught of a ship by one inch, and it is assumed that it is placed directly above the centre of flotation or disposed symmetrically before and abaft it. The weight required will change with a change of waterplane area and therefore with a change of draught, and for any particular draught it can be found from the following formula :—

TPI = the increase in displacement due to a uniform increase in the draught of one inch ;

$$= \frac{1}{35}\left[\frac{A \times 1}{12}\right] = \frac{A}{420} \text{ tons,}$$

where A is the waterplane area for a particular draught in square feet.

Trim and Change of Trim

Trim is the inclination of a ship in a fore-and-aft sense, and it is usually measured by the difference between her draughts forward and aft. If the draughts are the same the ship has no trim and she is said to float on an " even keel " ; if the draught forward is the greater she is said to trim " by the head," and if the draught aft is the greater she is said to trim " by the stern."

Change of trim is a change in the difference between the draught forward and the draught aft caused either by shifting weights forward or aft, or by adding or removing weights before or abaft the ship's centre of flotation. If a weight is moved forward or aft there will be no change in the ship's displacement or mean draught, and she is then assumed to incline about the transverse axis through the centre of flotation corresponding to her displacement. If a weight is added or removed, however, her displacement and draught will be altered, and provided the change of draught is not great, the ship can be assumed to trim about the transverse axis through the centre of flotation corresponding to her new displacement and draught.

When weights are shifted, added, or removed, the positions of the centres of gravity, buoyancy, and flotation will change in relation both to the ship and to themselves ; the waterplane area will also be changed, but unless the changes of weight are very considerable the relative changes of position of the various centres will be very little, and in practice they are disregarded unless very accurate estimations are required.

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The total change of trim is divided between the ends of the ship in the ratio of their distances from the centre of flotation. For rough calculations the draughts forward and aft may be assumed to change by half this change of trim. If, for example, the total change of trim is two inches by the head, it is assumed that the draught forward will be increased by one inch and the draught aft will be decreased by one inch.

Moment to change Trim One Inch (M.C.T.1″)

This moment depends on the displacement of the ship, her length and her longitudinal metacentric height; it will therefore vary with her condition of loading and is expressed in tons feet. The relationship between these factors is shown by the formula :—

$$\text{M.C.T.1}'' = \frac{\text{W} \times \text{GM}_\text{L}}{12 \times \text{L}}$$

where :—

W is the displacement of the ship in tons;

GM_L is the longitudinal metacentric height in feet; and

L is the length of the ship.

The change of trim caused by shifting a weight forward or aft can be found from the formula :—

$$\text{change of trim} = \frac{\text{w} \times \text{d}}{\text{M.C.T.1}''},$$

where :—

w is the weight in tons;

d is the distance in feet the weight has been shifted; and

M.C.T.1″ is the moment to change trim one inch.

Example :—

A ship with a displacement of 1,980 tons has a length of 220 feet between perpendiculars and a longitudinal metacentric height of 252 feet. 30 tons of oil fuel are pumped from one tank to another which lies 63 feet further forward. Before pumping was begun her draughts were 10 ft. 6 in. forward and 11 ft. 6 in. aft. Find her draughts after pumping is completed.

$$\text{M.C.T.1}'' = \frac{1980 \times 252}{12 \times 220} = 189 \text{ tons feet.}$$

$$\text{Total change of trim} = \frac{30 \times 63}{189} = 10 \text{ in. by the head.}$$

Therefore the new draughts will be :—

forward 10 ft. 11 ins.

aft 11 ft. 1 in.

If a weight is added before or abaft the centre of flotation the change of trim is found by assuming that the weight was first added directly above the centre of flotation and then shifted forward or aft to its position.

Example :—

The ship in the foregoing example in her original condition has a tons per

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inch immersion of 9. A weight of 27 tons is then placed in her No. 2 hold at a distance of 42 feet before her centre of flotation. Find her new draughts.

$$\text{Mean sinkage} = \frac{27}{9} = 3 \text{ in.}$$

in which condition the draughts would be :—

forward 10 ft. 9 in.
aft 11 ft. 9 in.

$$\text{Total change of trim} = \frac{27 \times 42}{189} = 6 \text{ in. by the head.}$$

The new draughts will therefore be :—

forward 11 ft.
aft 11 ft. 6 in.

If a weight is removed from a position before or abaft the centre of flotation the change of trim is found by assuming that the weight was first shifted to the centre of flotation and then removed.

Example : —

A ship is about to discharge cargo as follows :—20 and 45 tons at 105 and 80 feet, respectively, before her centre of flotation, and 30 and 22½ tons at 60 and 80 feet, respectively, abaft it. Her draughts are 20 ft. forward and 22 ft. aft, in which condition her tons per inch immersion is 29 and her moment to change trim one inch is 600 tons feet. Find her draughts after she has discharged her cargo.

The change of trim is first found by multiplying each weight by its distance from the centre of flotation, finding the sum totals of moments before and abaft the centre of flotation, then subtracting the lesser amount from the greater and finally dividing the result by the moment to change trim by one inch. Thus :—

$$\frac{(20 \times 105 + 45 \times 80) - (30 \times 60 + 22\tfrac{1}{2} \times 80)}{600} \text{ inches}$$

$$= \frac{2100}{600} = 3\tfrac{1}{2} \text{ in.}$$

The change of trim will be by the stern because the sum of the total moments before the centre of flotation is greater than that abaft it.

The draughts will therefore be approximately :—

forward 19 ft. 10¼ in.
aft 22 ft. 1¾ in.

The decrease of draught is then found by dividing the sum of the weights by the tons per inch immersion, thus :—

$$\frac{20 + 45 + 30 + 22\tfrac{1}{2}}{29} = 4 \text{ inches (approx.).}$$

The ship's draughts after discharging cargo will therefore be :—

forward 19 ft. 6¼ in.
aft 21 ft. 9¾ in.

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Change of Draught when passing from Salt Water to Fresh Water

The draught of a ship passing from salt water to fresh water will increase because salt water is denser than fresh water. The increase is usually small and can be calculated from the formula :—

$$S = \frac{W}{T}\left[\frac{d_s - d_f}{d_f}\right],$$

where :—

S is the sinkage in inches ;

W is the displacement in tons ;

T is the tons per inch immersion in salt water ;

d_s is the density of salt water in lb/ft.^{3} ;

d_f is the density of fresh water in lb/ft.^{3}

d_s and d_f are approximately 64 and 63 lb/ft.^{3}, respectively, so that the formula may be written in the simpler form :—

$$S = \frac{W}{63T}.$$

The estimation of this change of draught is important for a sea-going ship when loading her cargo some miles up a river, because when loading to her marks it determines to what extent the ship can be immersed above her appropriate load line and still conform to the *Load Line Regulations* when she reaches the sea.

In practice cargo ships are assigned a " fresh water allowance " which represents the change in inches of the mean draught of the ship in her deep load condition when she passes from salt to fresh water or *vice versa*. At river mouths, however, the water is neither entirely fresh nor entirely salt, and when estimating the change of mean draught allowance must be made for the different densities of the river water, salt water and fresh water. This is done by finding, by means of a hydrometer, the density of the river water at the place where the ship is lying and then calculating the change of mean draught by means of the formula :—

$$C = \frac{A \times d}{D},$$

where :—

C is the change of mean draught when passing from the river to the sea ;

A is the fresh water allowance assigned to the ship ;

d is the difference in density between sea water and the river water ; and

D is the difference in density between salt water and fresh water.

Example : —

The density of the water at a certain river port is 1,008 oz. per cu. ft. To what extent can an outward bound ship with a fresh water allowance of 6 inches be immersed below her load line ? Assuming that the density of fresh water is 1,000 oz. per cu. ft. and the density of the sea water off shore is 1,025 oz. per cu. ft. the change of mean draught will be :—

$$\frac{6 \times (1025 - 1008)}{1025 - 1000} = \frac{6 \times 17}{25} = 4 \text{ in. (approx.).}$$

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Remarks on Loading and Trim

When loading a vessel care must be taken to trim her so that she will handle well both in a seaway and in narrow waters, to ensure that she has sufficient buoyancy at bows and stern to ride the seas, and to avoid any concentrations of weight which may place undue stresses on her structure.

Handling Qualities

Any ship which is trimmed at all by the bows will probably be difficult to handle both in a seaway and in narrow waters because her pivoting point will then be shifted well forward and so will reduce the effect of her rudder. Most ships handle best when trimmed a little by the stern, and when " flying light " this trim is usually increased to ensure that the propeller and rudder are sufficiently immersed.

The trim of a cargo vessel with her machinery amidships is much easier to estimate and control than that of a vessel with her machinery aft, because in the former vessel the permanent weight is at her " tipping centre " and will therefore exert little moment before or abaft it, whereas in the latter vessel, which has her permanent weight right aft, it is difficult to estimate the changing effect of its moment about the " tipping centre " as cargo is loaded into the holds. In such vessels the danger lies in loading her down to her marks and then finding her trimmed by the head, when nothing can be done to correct it, except reloading the cargo, because by flooding the after ballast tanks the ship will be brought below her marks. To guard against this it is common practice to fill the fore peak tank or No. 1 ballast tank before loading, thus enabling any trim by the head to be corrected by pumping out these tanks.

Pitching

Any concentration of weight forward in a ship will reduce the buoyancy and increase the moment of inertia of her bows which will result in the ship being sluggish by the head, failing to rise to the seas, and burying her bows in them. She will then be liable to ship heavy seas when steaming head to sea which may not only strain her structure but also stave in her hatches. Any concentration of weight forward and aft will increase the moment of inertia of the ends of the ship and so increase the stresses of hogging, and may result in her breaking her back.

While a concentration of weights amidships will ensure that the bows and stern are buoyant it will increase the stresses of sagging, and the resultant lively pitching may also strain the ship's structure.

A rough compromise between these two extremes is to put 60 per cent. of the total weight of cargo in the midship holds, and distribute the remainder between the forward and after holds. The distribution of the cargo by volume, and therefore to a certain extent by weight, is, of course, governed by the shape of the ship, because the taper at bows and stern makes the forward and after holds much smaller than the midship holds.

Shearing Stresses

Because of the sub-division of a cargo vessel into several large spaces for the accommodation of her cargo and machinery, her hull is more subject to the stresses of shearing at the main transverse bulkheads than are the hulls of warships and liners which have a far greater degree of sub-division. Care must

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therefore be taken not to increase these stresses unduly by incorrectly distributing the weight of the cargo.

The shearing stresses involved are illustrated in Fig. 123 which shows an unladen cargo vessel with four holds and her machinery amidships. If the ship were separated into her five main sections and each were made watertight the bows and stern would float deeper in the water because their waterplane areas are small in comparison with their weight, the midship section would also float deeper because of the weight of the machinery in it, but the two remaining sections would float higher in the water because their waterplane areas are large in comparison with their weight. Thus, because of her shape and sub-division, unavoidable shearing stresses are embodied in her hull at the main transverse bulkheads.

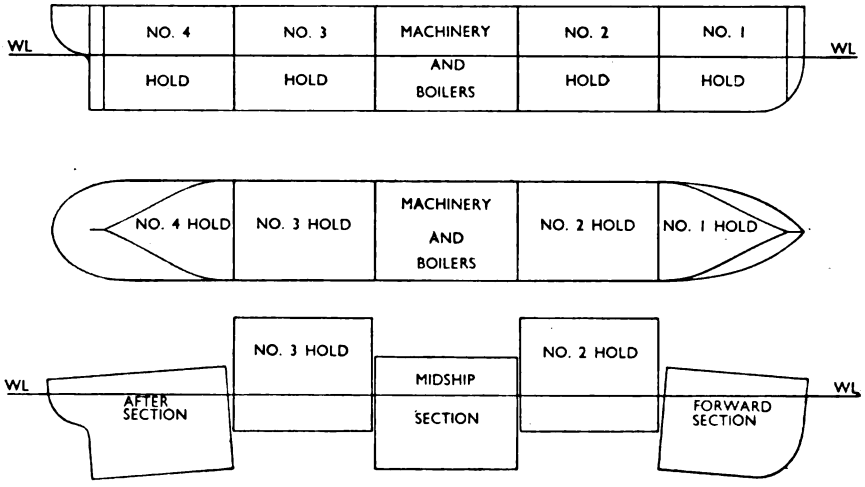

Fig. 123. Sheering stresses

To avoid increasing these stresses the heavier cargo should be placed in the main holds and the lighter cargo in the forward and after holds.

SUMMARY

The trim of a ship should be arranged so that she floats on an even keel or is trimmed a little by the stern ; she should never be trimmed by the head. The cargo should be distributed symmetrically before and abaft the ship's tipping centre, and the greater part of its weight should be amidships to ensure that her bows are buoyant, that she is stiff longitudinally, and to avoid any undue shearing stresses at her main transverse bulkheads.

STABILITY DATA AND THEIR USE

The stability problems with which the officers of a warship are faced are very different from those which confront the officers of a cargo ship. The former are not greatly concerned with loading problems because the stowage of a warship's ammunition, fuel and stores has been allocated by the designer, the difference between the conditions of deep and light load is not great and is

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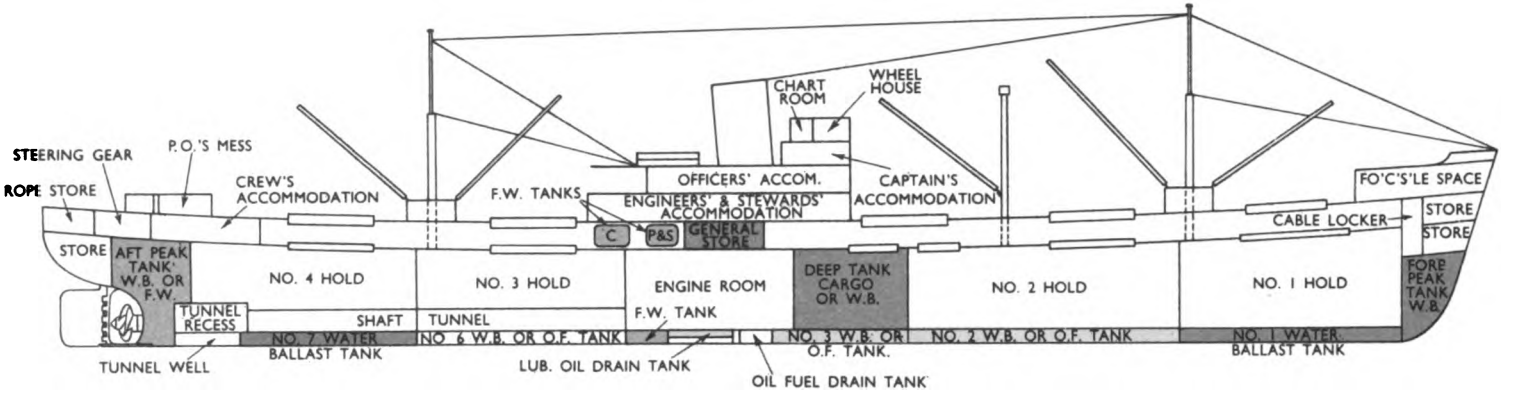
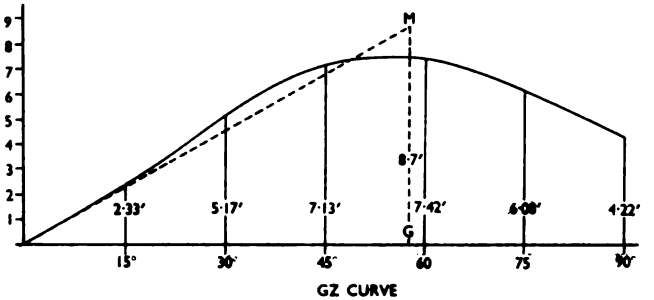


CONDITION — BALLAST DEPARTURE

LIGHT SHIP	3,774 TONS
OIL FUEL	944 TONS
FRESH WATER	234 TONS
FEED WATER	58 TONS
WATER BALLAST	1,991 TONS
LUBRICATING OIL	6 TONS
STORES	20 TONS
DISPLACEMENT	7,027 TONS



GZ CURVE

C.G ABOVE BASE	17·54 FT
METACENTRE ABOVE BASE	26·24 FT
G.M. PLUS	8·7 FT

DRAUGHT FORWARD	12′ 5¼″
DRAUGHT AFT	16′ 3¼″
MEAN DRAUGHT	14′ 4¼″

Fig. 124. EXAMPLE OF A STABILITY PLAN (i)

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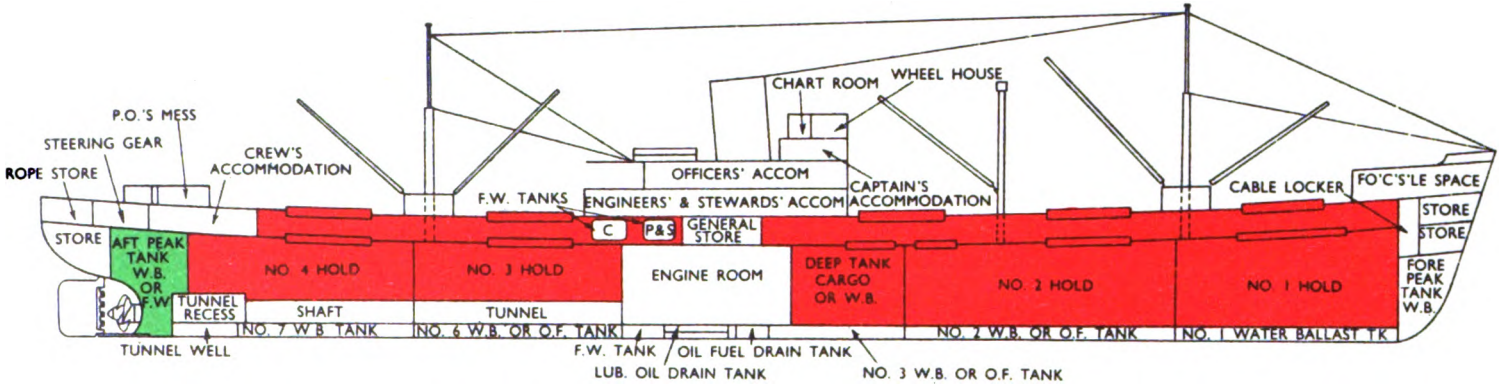
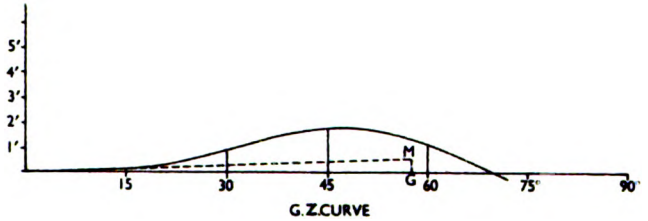


CONDITION—LOADED ARRIVAL

LIGHT SHIP	3,774 TONS
AFT PEAK TANK, S.W.	200 TONS
HOMOGENEOUS CARGO OF GRAIN STOWED AT 71.2 CU.FT. PER TON	8,138 TONS
DISPLACEMENT	12,112 TONS



G.Z.CURVE

C.G. ABOVE BASE	23.59 FT.
METACENTRE ABOVE BASE	23.89 FT.
G.M. PLUS	0.3 FT.

DRAUGHT FORWARD	22' 8¼"
DRAUGHT AFT	23' 11¼"
MEAN DRAUGHT	23' 3¾"

Fig. 125. EXAMPLE OF A STABILITY PLAN (ii)

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allowed for by the designer, and the manner in which the fuel tanks must be emptied, together with any ballasting which may be necessary, is also detailed by the designer. Provided therefore that those concerned in a warship closely follow the instructions of the designer, the embarkation, disembarkation, or consumption of fuel, stores and ammunition should not give rise to any considerable problems concerning the stability of the ship. When their ship is damaged below the water line, however, by torpedo or mine, for example, the officers of a warship are faced with the problem of having immediately to take the necessary measures to counter an unexpected inrush of water, so great that it may seriously affect the buoyancy and stability of their ship.

The officers of a cargo ship, on the other hand, are chiefly concerned with seeing that the cargo is loaded in such a manner as to ensure that their ship will have a reasonable margin of stability throughout a voyage, that she will handle well, and that any loss of stability from the consumption of fuel and stores can be countered if necessary by ballasting. Their problem though important is not urgent, and they can usually devote considerable time to it. Should their ship be damaged below the waterline there is little that can be done to regain any lost buoyancy or stability, because owing to the large spaces into which a cargo ship is divided, and the lack of watertight sub-division, pumping or counter-flooding are of little avail. Probably the most that can be done is to strengthen the bulkheads by shoring them and prevent the flood water from spreading to other parts of the ship.

Stability Data supplied to a Cargo Ship

There is unfortunately no standard method of preparing stability information for the use of ships' officers. It may be in the form of graphs or tables or both, and differences occur in each method. Generally speaking, however, the same kind of information is given for each ship, and the following information is typical of the stability data provided for a cargo vessel and the manner of their use.

Cross Curves of Stability

A typical graph of cross curves of stability is illustrated in Fig. 119 on page 402. The curves, each of which represents a certain angle of heel, are plotted on a horizontal axis of displacement and a vertical axis of the righting lever, and the graph is based on an arbitrarily selected position for the centre of gravity (in this case 21 feet above the keel). The graph gives the length of the righting lever in feet for any displacement at various angles of heel, always assuming that the centre of gravity remains at a height of 21 feet. From this graph the righting lever, or GZ, curve for a particular condition of loading and for a particular height of the centre of gravity can be drawn as described later.

Righting Lever, or GZ, Curves

These are drawn on a horizontal axis graduated in degrees to represent the various angles of heel for which the cross curves of stability have been drawn. The vertical axis represents in feet the length of the righting lever at the particular condition of loading for which the curve is drawn. The curve will therefore show at a glance the degree of stability of the ship throughout a range of heel from 0 to 90 degrees for any particular condition of loading.

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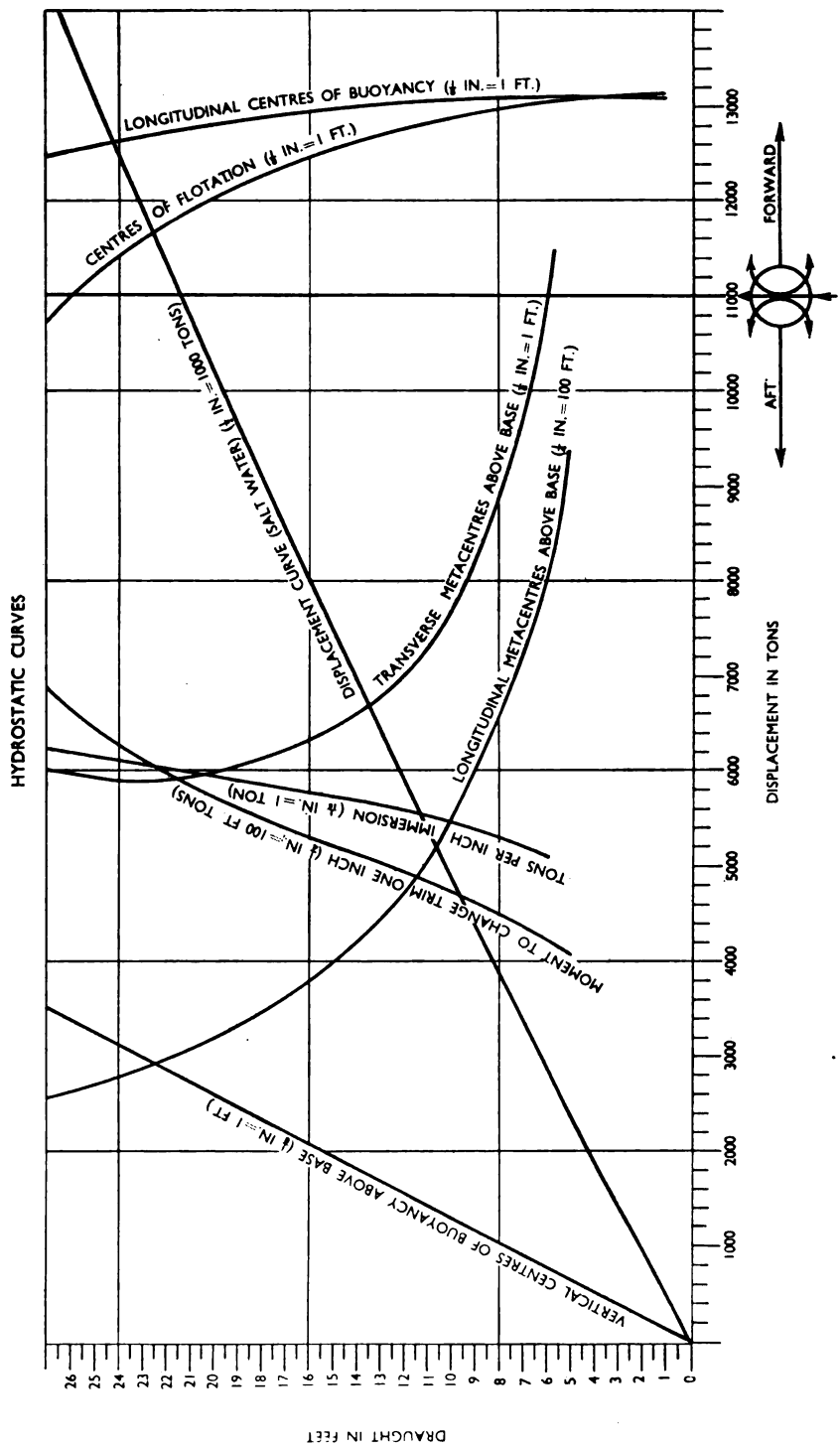
HYDROSTATIC CURVES
LONGITUDINAL CENTRES OF BUOYANCY (½ IN.=1 FT.)
CENTRES OF FLOTATION (½ IN.=1 FT.)
DISPLACEMENT CURVE (SALT WATER) (½ IN.=1000 TONS)
TRANSVERSE METACENTRES ABOVE BASE (½ IN.=1 FT.)
LONGITUDINAL METACENTRES ABOVE BASE (½ IN.=100 FT.)
TONS PER INCH IMMERSION (¼ IN.=1 TON)
MOMENT TO CHANGE TRIM ONE INCH (½ IN.=100 FT TONS)
VERTICAL CENTRES OF BUOYANCY ABOVE BASE (½ IN.=1 FT.)
DRAUGHT IN FEET
DISPLACEMENT IN TONS
FORWARD
AFT

Fig. 126, Typical example of hydrostatic curves

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These curves are usually drawn by the designer for the following conditions of loading :—" light ship," *i.e.*, with no water, fuel, stores, or cargo on board ; " ballast departure," *i.e.*, with fuel, stores, fresh and feed water on board, and with ballast tanks full, but with no cargo ; " ballast arrival," *i.e.*, similar to " ballast departure " but with most of the fuel, fresh water and stores consumed ; " loaded departure," *i.e.*, fully loaded with fuel, water and stores, and with all holds fully loaded with a homogeneous cargo ; and " loaded arrival," *i.e.*, similar to " loaded departure " but with most of the fuel, fresh water and stores consumed. Two typical examples are illustrated in Figs. 124 and 125 (between pages 418 and 419).

These are the extreme conditions of loading and from them the seaman can estimate at a glance the degree of stability of his ship through the range of conditions in which she is liable to be loaded. GZ curves can be drawn for any particular condition of loading as described later.

Hydrostatic Curves

Those factors affecting the stability and trim of a ship which depend solely on the underwater form of the hull can be depicted in the form of curves on a graph based on the draught of the ship. Such curves are termed " hydrostatic curves " and typical examples are described below and illustrated in Fig. 126.

The horizontal axis of the graph is graduated in tons displacement, and the vertical axis, which is graduated in feet, represents the draught of the ship.

Displacement Curve.—This curve approximates to a straight line, and from it can be found the displacement of the ship in salt water for a given draught. A separate curve for fresh water is often given for ships which may navigate in rivers or inland waters.

Vertical Centres of Buoyancy above Base.—This curve also approximates to a straight line and gives the height of the centre of buoyancy above the keel for a given draught. It is measured horizontally from the vertical axis to the scale stated against the curve.

Transverse and Longitudinal Metacentres above Base.—The heights of the transverse and longitudinal metacentres above the keel for any particular draught are given by these two curves. The heights are measured horizontally from the vertical axis to the scale shown against each curve.

Moment to Change Trim One Inch.—This gives the moment in tons feet which is required to change the trim of the ship by one inch at any particular draught, and it is measured horizontally from the vertical axis to the scale shown against the curve.

Tons per Inch Immersion.—This gives the weight required to be added or removed in order to change the mean draught of the ship by one inch at any particular draught. It is measured horizontally from the vertical axis to the scale shown against the curve.

Longitudinal Centres of Buoyancy.—This curve gives the longitudinal distance of the centre of buoyancy at any particular draught from amidships. Amidships is indicated on the graph by the conventional mark comprising a circle, two

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TANK CAPACITIES, TRIMMING SCALES & FREE SURFACE

COMPARTMENT	FRAMES	CAPACITY CU FT	TONS OIL FUEL AT 39cf/T	TONS WATER BALLAST AT 35cf/T.	TONS FRESH WATER AT 36cf/T	EFFECTS ON DRAUGHTS BY FILLING TANK					L.C.G. ABOUT MIDSHIPS	V.C.G. ABOVE BASE	FREE SURFACE MOMENTS		
						TONS ADDED	23' 0" W.L. FOR'D	23' 0" W.L. AFT	17' 0" W.L. FOR'D	17' 0" W.L. AFT			TONS OIL AT 39cf/T.	TONS W.B. AT 35cf/T.	TONS F.W. AT 36cf/T.
NO. 1 C.D.B. TANK	139—164	2,634	67·5	75		80	+ 6⅛	−3½	+7½	−4½	160·7F	2·47	378	419	
NO. 2 .. .. P	110—139	4,684	120	134		275	+16½	−5⅞	+17⅛	−6½	101·88F	2·11	3,299	3,701	*
NO. 2 .. .. S	..	4,684	120	134							101·88F	2·11			
NO. 3 .. .. P	81—110	6,693	171·5	191		390	+13½	+2½	+13⅜	−2⅜	36·54F	2·29	7,004	7,818	*
NO. 3 .. .. S	..	6,693	171·5	191							36·54F	2·29			
F.W. TANK AFT	STERN-B.	517			14·2	14·2	−1	+1⅜	−1½	+1⅝	226·21A	31·01			
TOTAL DEEP TANKS, PEAKS, ETC.		66,142	64	1,704	96·0										
GRAND TOTAL		114,293	1192·0	2,961	211·0										

TO OBTAIN THE REDUCTION IN METACENTRIC HEIGHT DUE TO FREE SURFACE IN THE TANKS, DIVIDE THE MOMENT GIVEN ABOVE BY THE DISPLACEMENT (TONS) OF THE SHIP IN THE CONDITION UNDER CONSIDERATION. THE MOMENTS MARKED THUS * INCLUDE BOTH PORT & STARBOARD TANKS THE PORT OR STARBOARD FIGURES SEPARATELY BEING HALF THOSE STATED.

N.B.—THESE COLUMNS ARE INCLUDED FOR USE IN ASSESSING CHANGES OF TRIM BY LOADING

CARGO SPACE CAPACITIES

COMPARTMENT	FRAMES	GRAIN (CUBIC FEET)	BALE (CUBIC FEET)	EFFECT OF PLACING 100 TONS AT HATCH CENTRE IN HOLDS & TWEEN DKS. CENTRE OF COMPARTMENT ELSEWHERE				L.C.G. ABOUT MIDSHIPS	V.C.G. ABOVE BASE
				23' 0" W.L. FOR'D	23' 0" W.L. AFT	17' 0" W.L. FOR'D	17' 0" W.L. AFT		
NO. 1 HOLD	139—164	38,748	34,130	+8⅜	−4⅜	+9⅜	−5⅛	158·45F	16·42
NO. 2 ..	110—139	68,331	62,357	+6¼	−2¼	+6⅝	−2⅜	111·89F.	13·72
NO. 3 ..	81—110	60,246	52,961	+4	—	+4¼	—	35·61F	22·63
TONNAGE WELL		1,634	1,548	−5⅜	+9⅜	−7	+11¼	190·21A	35·91
TOTAL DEEP TANKS, SPECIAL CARGO, ETC.		91,225	83,521						
GRAND TOTAL		637,658	566,242						

NOTE:—TRIM FIGURES ARE CALCULATED ON MEAN DRAUGHTS OF 23' 0" AND 17' 0" AND ARE CORRECT FOR THOSE DRAUGHTS, BUT ONLY APPROXIMATE FOR ANY OTHER.

N.B.—THESE COLUMNS ARE INCLUDED FOR USE IN ASSESSING CHANGES OF TRIM BY LOADING.

Fig. 127. Typical example of trim tables

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semi-circles and a vertical arrow. In this example the LCB lies before amidships, and the distance is measured horizontally from the line indicated to the scale shown against the curve.

Centre of Flotation.—This gives the longitudinal distance of the centre of the waterplane area at any particular draught from amidships. It is about a transverse axis through this point that the ship is assumed to trim, and its position is measured in a similar manner to that of the LCB. In this example it will be seen that the centre of flotation coincides with amidships when her draught is 26 feet.

Trim Tables

The effects on the trim of the ship of loading or discharging cargo, and filling and emptying the various tanks, can be estimated from these tables. They also provide a means of estimating the position of the ship's centre of gravity at any condition of loading. Two separate tables are usually provided, one for the cargo spaces and the other for the tanks, and a typical example of them is shown in Fig. 127.

The trim table for the cargo spaces usually gives the grain and bale capacity of each space, the effect on the draughts forward and aft of placing 100 tons centrally on the deck of each space when the ship is floating at two or more selected mean draughts, the height of the centre of gravity of each space (*i.e.*, the centre of its volume) above the keel, and the distance of the centre of gravity of each space before or abaft either the centre of flotation or the transverse centre-line.

The trim table for the tanks gives the capacity of each tank in cubic feet, the quantity of fuel, salt water or fresh water in tons, which each will hold, the effect on the draughts of filling any particular tank, and the positions of the vertical and longitudinal centres of gravity of each tank. It also gives the free-surface moment of each tank when in the slack condition, which enables the reduction of the metacentric height due to free-surface effects to be quickly calculated by dividing the given moment by the displacement of the ship.

Use of Stability Data

The following example shows how stability data about a cargo vessel can be used to estimate her metacentric height and degree of stability at any particular condition of loading. The information shown in Figs. 119 and 126 on pages 402 and 420 respectively, is used, and the problem is to find the metacentric height, and draw the stability curve of the ship, when in her " ballast departure " condition.

To Find the Metacentric Height

First it is necessary to calculate the height of her centre of gravity above base (KG), by first multiplying the weight of the liquid (or stores) in each tank (or compartment) by the height of its centre of gravity above base (VCG) taken from the ship's trim tables and so obtaining the moment above base of

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each item, and then dividing the sum total of the moments by the sum total of the weights, thus :—

ITEM	WEIGHT IN TONS		HEIGHT OF VCG ABOVE BASE IN FEET		MOMENT ABOVE BASE IN TONS FEET
Hull and Machinery ...	3,774	×	22·99	=	86,764
No. 1 Tank—S.W. ...	199	×	2·5	=	498
No. 2 Tank—O.F.... ...	388	×	2·0	=	776
No. 3 Tank—O.F.... ...	204	×	2·0	=	408
No. 4 Tank—O.F. (P & S)...	104	×	2·0	=	208
No. 5 Tank—F.W. (P & S)	58	×	2·0	=	116
No. 6 Tank—O.F.... ...	248	×	2·2	=	546
No. 7 Tank—S.W. ...	161	×	2·5	=	402
Fore-peak Tank—S.W. ...	124	×	18·0	=	2,232
Aft-peak Tank—F.W. ...	194	×	23·0	=	4,462
Deep Tank—S.W.... ...	1,507	×	16·5	=	24,866
Lub. Oil Tank	6	×	3·0	=	18
Dom. Water Tank ...	40	×	33·0	=	1,320
Stores	20	×	33·0	=	660
Total weight	= 7,027 tons		Total moment =		123,276 tn. ft

$$\text{Therefore KG} = \frac{123276}{7027} = 17{\cdot}54 \text{ feet}$$

By reference to the hydrostatic curves (Fig. 126) it will be found from the displacement curve that at a displacement of 7,027 tons the mean draught of the ship will be 14 ft. 4½ in., and from the transverse metacentric curve it will be found that at this draught the height of the metacentre above base (KM) will be 26·24 feet. In this condition the ship's metacentric height (GM) will therefore be KM — KG or :—

$$\text{GM} = 26{\cdot}24 - 17{\cdot}54 = 8{\cdot}7 \text{ feet}$$

The GM thus obtained is calculated on the assumption that all tanks are pressed up. In practice, however, a correction must be made to allow for slack tanks and the adverse effect of free-surface liquids on the GM.

By reference to the trim tables the free-surface moment of each tank is given, and the consequent reduction of metacentric height is obtained by correcting each moment for the density of the liquid, adding the corrected moments together and dividing by the displacement of the ship.

The free-surface effect may be given in terms of fresh water only, or in terms of fresh and salt water, and oil fuel. If a tank is filled with any liquid other than that for which the free-surface effect was calculated, the stated effect must be multiplied by a factor representing the relative density of the two liquids.

To Draw the Stability Curve

The righting lever (or GZ) ordinates required for drawing the stability curve are obtained from the cross curves of stability (Fig. 119), but because these are drawn for an arbitrary height of the centre of gravity of 21 feet above base a correction must be made to each ordinate so that it corresponds with the height of the actual centre of gravity, namely, 17·54 feet.

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The GZ ordinates obtained from the cross curves are corrected for the position of the actual centre of gravity by means of the equation :—

$$GZ = gz \text{ (plus or minus) } Gg \sin \theta,$$

where :—

GZ is the corrected ordinate ;

gz is the ordinate obtained from the curves ;

Gg is the difference between the height of the centre of gravity for which the curves were drawn and the height of the centre of gravity for the condition for which the stability curve is to be drawn ; (the sign is positive if the arbitrarily selected centre of gravity is higher than the actual centre of gravity, and negative if it is lower) ; and

θ is the angle of heel.

The GZ ordinates are therefore found in the following manner :—

ANGLE OF HEEL	SINE OF ANGLE FROM TABLES	GZ LEVER FROM CROSS CURVES	Gg SIN θ	GZ LEVERS FOR STABILITY CURVE
15°	0·259	1·43	0·90	2·33
30°	0·500	3·44	1·73	5·17
45°	0·707	4·68	2·45	7·13
60°	0·866	4·42	3·00	7·42
75°	0·965	2·74	3·34	6·08
90°	1·000	0·76	3·46	4·22

On a horizontal axis graduated in degrees and with a vertical axis graduated in feet, to any suitable scale, the ordinates shown in the right-hand column are set up at their corresponding angles of heel, and the stability curve over the range of 15 to 90 degrees is then drawn (see Fig. 128).

The curve must pass through the origin of the vertical and horizontal axes of the graph, and at small angles of heel it always approximates to a straight line, whose slope is given by the equation $GZ = GM \sin \theta = GM\ \theta$ for small angles where θ is the angle of heel in radians.

To complete the curve, therefore, at an angle of heel equivalent to one radian (57·3°) set up an ordinate equivalent to the metacentric height (say

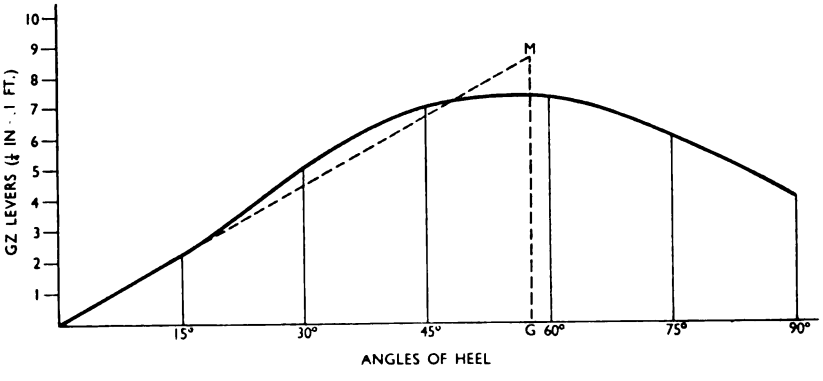

Fig. 128. A GZ curve

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H.M.S. EMERALD

STATEMENT of METACENTRIC HEIGHTS and STABILITY Based on an Inclining Experiment made on H.M.S. EMERALD on 3RD APRIL 1943

Conditions	Feet	Remarks
A. Average Action Condition.		
The Ship when floating at a mean draught of 19 feet 6¼ inches, fully equipped, 1. (Cruisers and below), with all oil fuel tanks half full (*i.e.*, with 920 tons of oil), ~~2. (Capital ships, aircraft carriers, depot ships and monitors) with all double bottom and cross bunker oil fuel tanks half full, all wing oil fuel tanks full (*i.e.*, with ..... tons of oil), water protection compartments in use (*i.e.*, with ..... tons water protection), and with reserve feed tanks full.~~ has a metacentric height of	3·2	
B. Extreme Deep Condition.		
The Ship when floating at a mean draught of 21 feet 1 inches, fully equipped, with all oil fuel tanks full (*i.e.*, with 1840 tons of oil), ~~water protection compartments in use (*i.e.*, with ..... tons of water protection)~~, and with reserve feed tanks full, has a metacentric height of	3·7	
C. Light Condition.		
The Ship when lightened to a mean draught of 17 feet 0¾ inches, *i.e.*, when boilers and feed tanks are at working height, engine condensers full, one half the Central stores consumed, no fuel, water (including reserve feed), provisions, Canteen or Officers' stores on board, has a metacentric height of	2·0	

	Degrees			
	A	B	C	
The angles at which the Ship reaches her maximum righting moment in the above conditions, and beyond which the righting moment diminishes, are about	44	45	39	In arriving at these results, the ship is assumed to be intact with all external openings closed
The angles at which her stability entirely vanishes in these conditions are about	89	OVER 90	71	

NOTES :— (1) So far as stability is concerned the fuel and water may be worked in any manner desired by the Commanding Officer, but it is desirable to avoid having more tanks slack than is necessary

(2) In ships provided with Flooding Boards attention is directed to the information thereon concerning the procedure for correcting heel and trim in the event of damage to the ship

(3) The "mean draught" is that obtained from the draught marks

(4) In the above, the fuel tanks are termed "half full" or "full" when they are filled to 47½% or 95% respectively of their total capacity

(5) The "Average Action Condition," as defined above, is also used for the Flooding Board and Damage Control calculations

Admiralty, , 1943

Director of Naval Construction.

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Fig. 129. Example of stability statement

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8·5 feet in this case allowing for slack tanks), and join the upper extremity of the ordinate to the origin. Then fair the curve from the 15° ordinate into the straight line.

The height of the centre of gravity, and therefore the metacentric height and stability curve, can be found for any condition of loading in the manner just described.

When considering the change of the centre of gravity due to loading cargo, if the cargo is homogeneous its centre of gravity will lie at the centre of its volume, but if it is a general cargo the centre of gravity of each item, or parcel of items, in a cargo space must be assessed separately according to its nature and position, and then be combined with the others to give the centre of gravity of all the cargo stowed in a particular space.

Stability Data supplied to a Warship

Apart from the possible results of action damage, the variations in the loading of a warship are very small in comparison with those of a cargo vessel, and the stability data supplied to a warship therefore differ in form from those provided for a cargo vessel and are not nearly so detailed.

In wartime a warship must always be maintained in the highest possible condition of stability to ensure that she has the best chance of surviving even when seriously damaged below water. To fulfil this requirement it is usually necessary in cruisers and smaller vessels, where the weight of oil fuel and ammunition forms a greater proportion of the ship's displacement than in larger vessels, to arrange for the consumption of the oil fuel in a particular manner and also to flood certain tanks. These instructions are included in the stability data.

It may occasionally be necessary in special circumstances to use a warship for carrying cargo, but this should be done with discretion and only after a careful review of all the circumstances, because, apart from considerations of space, carrying cargo will probably reduce her stability to an extent which will leave an insufficient margin to enable the ship to withstand damage.

All stability data provided for a warship will be found in her *Ship's Book*, and additional copies are provided for use in the ship's ABCD headquarters.

STABILITY STATEMENT

The Director of Naval Construction, provides every ship with a " Stability Statement," and it includes a certificate signed by him or his deputy to the effect that the stability of the ship is satisfactory. It is always made out for three particular conditions of loading, known as the " deep," the " average action " or " half oil," and the " light " conditions (see Fig. 129).

For each of these conditions the mean draught, the metacentric height, the angle of maximum righting lever, and the range of stability are given.

GZ CURVES

For each of the three conditions referred to on the Stability Statement, GZ or righting lever curves are also supplied.

HYDROSTATIC CURVES

These are generally similar to those supplied to cargo ships (see pages 420 and 421).

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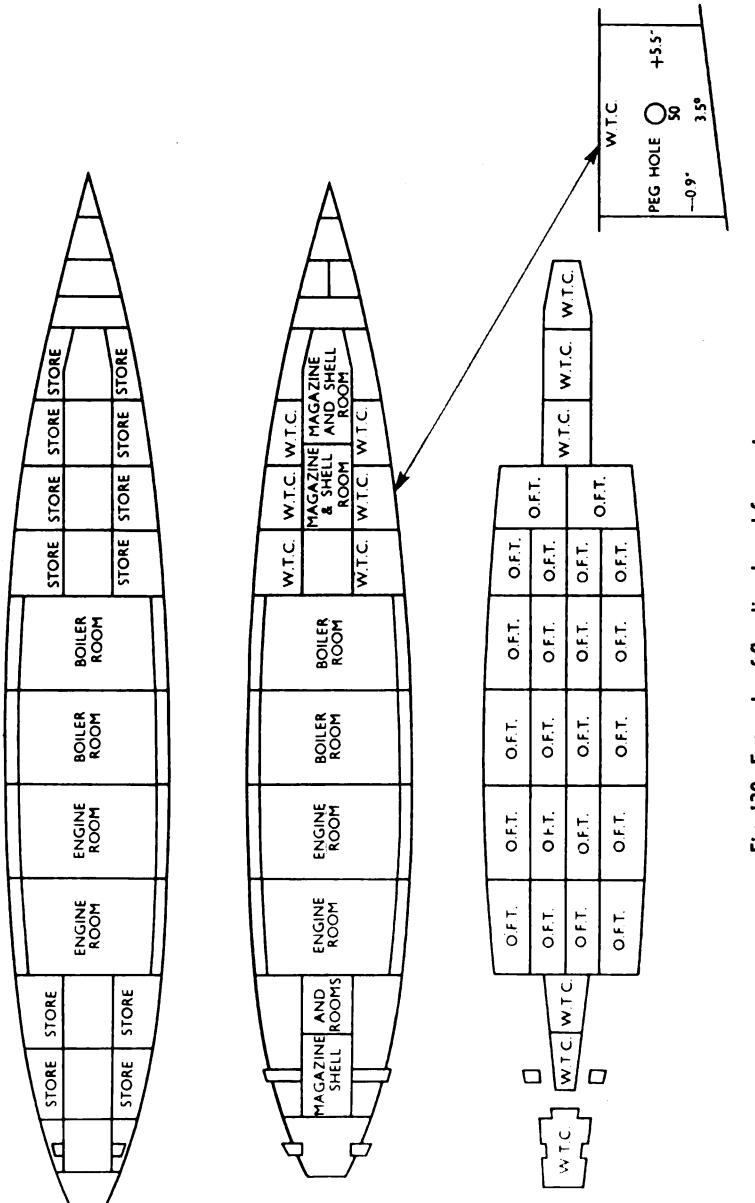

Fig. 130. Example of flooding board for cruiser

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PUMPING AND FLOODING BOARD

In addition to the Stability Statement which concerns the stability of the ship in any normal undamaged condition, cruisers and larger ships are provided with " pumping and flooding boards," which enable the ship's officers to estimate the effects of any damage and the consequent flooding on the stability of the ship, and the measures necessary to counter them.

The so-called boards consist of a series of deck plans of the ship from the hold up to and including the deck immediately below the deep load waterline (see Fig. 130). On each plan are shown the longitudinal and transverse watertight bulkheads, so that it can be seen at a glance which compartments can be flooded directly from the sea, and which may be flooded if the damage internally is extensive.

The effects on the displacement, heel and trim of the ship of flooding any compartment are shown by figures marked against each compartment. These figures are calculated on the assumption that the ship is initially in the " average action " condition.

Use of the Flooding Board.—Once it is known which compartments are flooded, the figures for each compartment can be added up to give the total " flooding-board heel." If the ship is then stable she can be restored to an approximately upright position either by transferring liquids within her or by counter-flooding, and each method is described below.

Transference of Liquids.—The effect of transferring a liquid from a compartment on the damaged or low side to another on the undamaged or high side is the sum of the heels for each compartment. Thus for a given quantity of liquid the effect is double that of counter-flooding, and has the added advantage of not reducing the ship's reserve of buoyancy.

Counter-flooding.—This entails flooding compartments on the undamaged or high side of the ship to an extent which will equal the total " flooding-board heel " caused by the damage. Its effect is only half that of transferring liquids and it has the added disadvantage of decreasing the ship's reserve of buoyancy and increasing her draught.

The two methods are described below and illustrated by Fig. 131, overleaf.

Suppose that the damage has resulted in P_3 and P_5 tanks being flooded. The resultant flooding-board heel will be 2·4° + 3·8°, a total of 6·2°. The ship can be restored to her upright position by :—

transferring the liquids already in tanks P_1 and P_7 (total capacity 129 tons) to the empty tanks S_2, S_4 and S_6 (total capacity 129 tons) thereby providing heels of 1·6°, 2·6°, 0·6°, 0·8° and 0·6°, a total flooding-board heel of 6·2° ; or

counter-flooding by filling the empty tanks S_3 and S_5, thus providing heels of 3·8° and 2·4°, a total flooding-board heel of 6·2°.

To distinguish clearly between flooding due to damage and any counter-flooding, pegs of different colours are used for each and are inserted in holes provided for this purpose in each compartment marked on the board.

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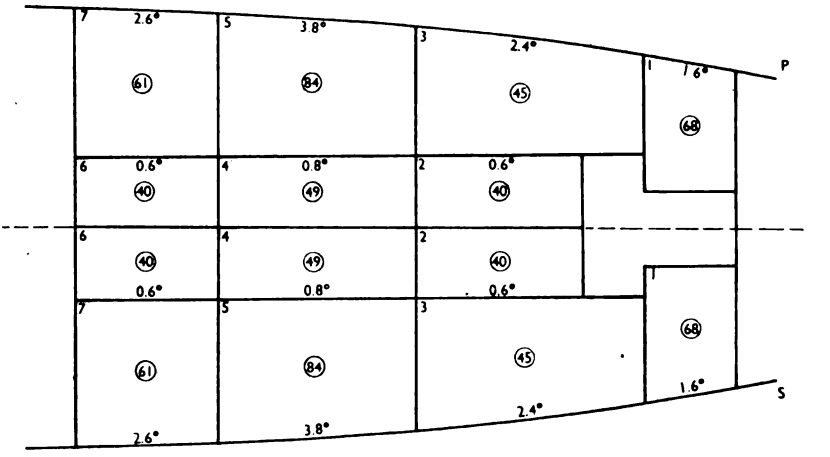

Fig. 131. Example of use of flooding board

Remarks on Flooding and Countermeasures

When practicable the list of a damaged ship should be corrected by transferring liquid from one compartment to another, because this does not entail any loss of the ship's reserve of buoyancy. It is however, a rather slow method, involves additional free-surface effects during the transfer, and in warships where a quick return to the upright may be essential, counter-flooding may be preferable.

Counter-flooding is a quick method of curing a list, and in large cruisers and all larger warships suitable wing compartments are fitted with flooding valves so that they can be filled quickly direct from the sea. If a ship is badly damaged and listing ten degrees or more, counter-flooding should be resorted to immediately.

It should be realised, however, that counter-flooding has its disadvantages. It reduces the reserve of buoyancy, and sinks the ship lower in the water and so decreases her speed and manœuvrability. It should therefore only be used to the extent necessary to get the ship back to a manageable state as quickly as possible, which generally means reducing the list to about six degrees, at which angle the ship can be manœuvred and fought. Thereafter such measures as transferring liquids, repairing damage and pumping out compartments will further reduce the list and may even allow some reserve of buoyancy to be regained by pumping out compartments which have been counter-flooded.

In small cruisers, destroyers, and smaller ships, where there is little longitudinal sub-division, damage below the waterline may result in the ship taking large quantities of flood water into one or more of her main compartments, her engine and boiler rooms for example. The free-surface effect of the large area of this water may reduce the metacentric height to such an extent that the ship will have a negative metacentric height and float unstably, lolling from side to side under the influence of the waves or wind. In such a case it would be dangerous to attempt to correct any heel by transferring liquids or by counter-flooding ; the only counter measures which should then be attempted, until a degree of positive metacentric height has been regained, are :—

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(i) isolating, sub-dividing and pumping out any compartments containing free-surface liquids ;

(ii) filling to the crown tanks low down in the ship, including those which already contain liquids ;

(iii) jettisoning movable topweight symmetrically from about the longitudinal centre-line.

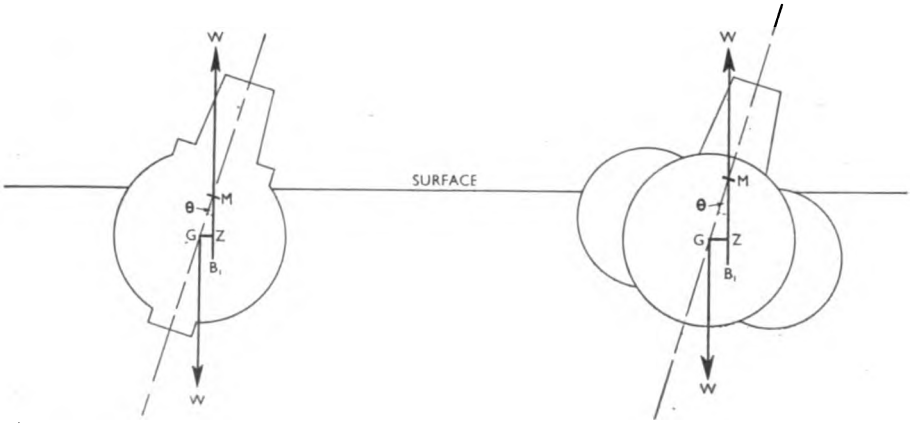
To summarise, transference of liquids should be regarded generally as being the best method of correcting a list. When, however, it is essential that the damaged ship should be returned to the upright as quickly as possible, counter-flooding is preferable, but it should be done as soon as possible after the ship has listed, its use should be restricted to the minimum necessary to bring the ship to a safe or manageable state, and later, when other measures are in hand, it should be reduced as much as possible. In small ships it is imperative to distinguish between the conditions of list and loll because the remedies for each are so different ; if the ship is in a state of loll it must be corrected before any measures are taken to counter list.

STABILITY AND TRIM OF SUBMARINES

This section is not intended to be read as a treatise on the stability and trim of submarines, but merely to indicate the great differences between the problems of stability of these vessels and those of surface ships.

Transverse Stability

The transverse stability of a submarine floating on the surface can be estimated in a similar manner to that of a surface ship. From Fig. 132 it can be seen that as the vessel heels her centre of buoyancy (B) moves to B_1 on the low side, producing a righting couple, $W \times GZ$, where $GZ = GM \sin \theta$ for small angles of heel. At larger angles of heel the saddle-tank type of submarine (Fig. 132(ii)) is likely to have better stability than the single-hull type (Fig. 132 (i)) because of the broader waterplane area of the former.



(i) (ii)

Fig. 132. Transverse stability of surfaced submarine

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When a submarine is completely submerged, however, she has no waterplane and therefore no waterplane inertia, and her metacentre (M) will then coincide with her centre of buoyancy (B). Moreover, B will become a fixed point irrespective of any angle of inclination because the underwater form of the vessel will not change as she heels. In order, therefore, to provide the necessary righting moment when the submarine is heeled, her centre of gravity (G) must be below her centre of buoyancy (B) as shown in Fig. 133 (i) and (ii), thus providing the righting lever (GZ) which will be equal to BG sin θ. The distance BG can be

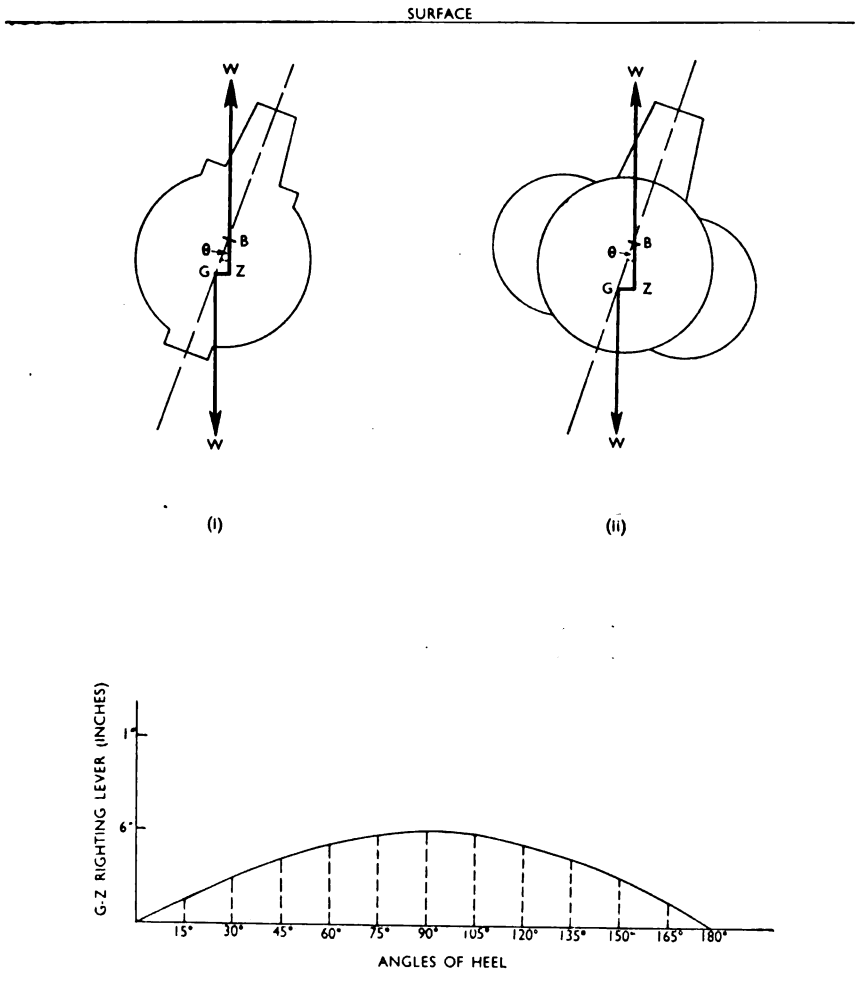

Fig. 133. Longitudinal stability of a submerged submarine

taken as constant, if any small movement of G due to free-surface liquids is disregarded, and the GZ curve will therefore become a curve of sines as shown in in Fig. 133 (iii). From this curve it will be seen that the angle of maximum GZ is 90 degrees, that at this angle GZ = BG (sin θ = sin 90 = 1), and that the range of stability is 180° (sin θ = sin 180 = 0, and therefore GZ = 0).

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The length of BG gives a measure of the stability of a submerged submarine, and corresponds to the GM of a surface ship. The BG of a submerged submarine is usually less than her GM when on the surface, except in single-hulled vessels where the reverse is usually the case.

Longitudinal Stability and Trim

The longitudinal stability of a submarine when on the surface can be estimated in the same way as that of a surface vessel from the formula :—

M.C.T.1" = $\frac{W \times GM_L}{12L}$ as described on page 414.

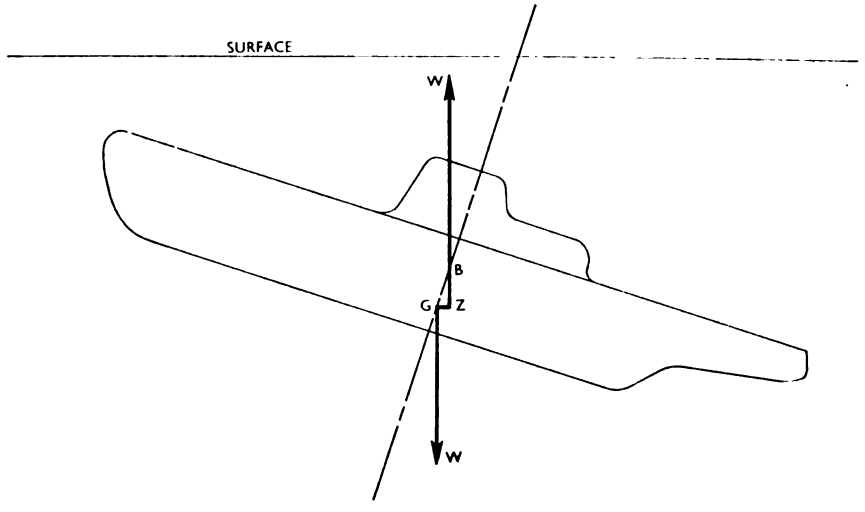

Fig. 134. Transverse stability of submerged submarine

When the submarine is submerged, however, her longitudinal metacentre (M_L) will, like her transverse metacentre, coincide with her centre of buoyancy, and her GM_L will then be equal to BG (see Fig. 134). Since the length of BG is usually only about 6 inches it will be seen that her longitudinal righting moment is very small indeed, and that consequently she will be very tender longitudinally when submerged. This tenderness makes it necessary to limit and accurately control the movement of any weights along the vessel ; it is, however, an advantage because it enables her trim to be controlled by reasonably small hydroplanes, and ensures that she can change depth rapidly which would not be practicable if she had the longitudinal stiffness of a surface ship.

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CHAPTER XIX

Cargo Stowage

THE EFFICIENT, economical and safe stowage of a shipment of cargo is a complex problem which needs a thorough knowledge and considerable experience of the subject. This chapter is intended only to explain the principles and main features of cargo transportation. Various text-books on this subject have been written, of which *Stowage**, by Captain R. E. Thomas, is generally recognised by the British Merchant Navy as the leading authority on the subject, and the reader is advised to consult this book when confronted with a particular stowage problem.

Glossary of Terms

APRON—the quayside between a shed and the edge of a quay.

BACKWEIGHT OR DEADMAN RIG—a rig used largely in the U.S.A. with a swinging derrick to return it to a position plumbing the hold after it has hoisted out a load. A lazy guy is shackled to the derrick head, then rove through the head block of another derrick rigged to plumb the opposite side of the hold, and a suitable weight is slung on its end. (See Fig. 135 on page 438.)

BALE CAPACITY—the cargo space available within a ship or a hold, measured in cubic feet from the lower edges of the beams and the inner edges of the cargo battens across the side frames. It is therefore less than the grain capacity (which see) by the amount of space between the beams and the frames.

BETWEEN DECK—see 'TWEEN DECK.

BILGE AND CANTLINE—the method of stowing barrels or casks with the bilges of the casks of the upper tiers over the cantlines of the casks of the lower tiers (see Fig. 139 on page 450).

BILL OF LADING—a receipt for goods loaded in a ship. It gives the terms on which the goods are accepted as freight, and is signed by the person who contracts to carry them, or his representative (*e.g.*, the master of the ship). Although primarily a receipt, a bill of lading is also usually treated as a negotiable document of title representing the goods to which it relates.

BOOBY HATCH—a small additional hatchway giving entrance to a hold.

BREAKING-OUT—the operation of breaking bulk in a hold when starting to discharge cargo.

BREAKING BULK—shifting the first few packages in a closely stowed hold, the better to get at the remainder.

BROKEN STOWAGE—the spaces between items or parcels of cargo when stowed in a hold. It may be due to bad stowage, irregular sizes or shapes of the various items of cargo, the size and shape of the hold, stanchions and similar fittings in way of the cargo, or the need to use a lot of dunnage. An arbitrary allowance for broken stowage, based on experience, is made when planning the stowage of different types of cargo in the same hold.

* Published by Messrs. Brown, Son and Ferguson of Glasgow.

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BULK CARGO—any type of dry or liquid cargo such as grain, coal, ores and petroleum which can be stowed in bulk.

BULL-ROPE—a rope used for hauling cargo from the wings or ends of a hold to its centre or *vice versa*, or a rope used as a steadying line to guide a lift clear of obstructions in its path.

CARGO BATTENS—removable wooden battens fitted across the inner edges of the frames in a hold to prevent contact between cargo of a general nature and the ship's side. In addition to protecting the cargo from damage by sweating of the ship's sides they provide an air space for ventilation.

CARGO DEADWEIGHT—the weight in tons of an item, or parcel, of cargo. Freightage dues for cargo which stows at less than 40 cu. ft. per ton weight are computed from the deadweight of the cargo.

CEILING—the wooden deck fitted over the bottoms of the holds of some ships which carry a general cargo. Its purpose is to prevent contact between the cargo and the inner bottom or the tank tops, to provide a ventilation space under the cargo, and drainage to the bilges for any liquid or moisture from the cargo or the bulkheads.

CORDWOOD—small pieces of wood used as dunnage.

DEADMAN RIG—see BACKWEIGHT RIG.

DEMURRAGE—compensation paid to the owner of a vessel which has been delayed in port beyond the agreed time.

DERRICK TABLE OR MAST PLATFORM—a tabernacle built round the foot of a mast for supporting the heels of the derricks and occasionally the winches.

DESPATCH MONEY—a bonus paid by the shipowner to the charterer if his ship is loaded or discharged before the period agreed upon.

DRIFT—the clearance between the head block of a derrick and the bulwarks, the quayside or any obstruction in its path.

DUNNAGE—baulks of timber, quartering, planks, cordwood, matting, sacking, cloths and other similar materials, used for shoring, chocking, packing, separating and ventilating cargo.

FIDDLEY—the space above the boiler and engine rooms of a ship.

FLOORING-OUT—spreading dunnage or stowing cargo over the bottom of a hold.

FULL AND DOWN—describes the condition of a vessel when her holds are filled to capacity and she is loaded down to her maximum legal draught.

GANTRY.—an overhanging or spanning structure.

GENERAL CARGO—A cargo comprising different commodities as distinct from homogeneous cargo such as grain or liquids in bulk.

GIN FALL—another name for the whip, runner, or purchase of a derrick.

GRAIN CAPACITY—cargo space available within a ship or a hold, measured in cubic feet from the sides of the ship and the deck-heads of the holds. It is therefore greater than the bale capacity (which see) by the amount of space between the frames and the beams.

GROSS WEIGHT—the total weight of a case and its contents.

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HAND HOOK—a pointed steel hook with a T-handle used by stevedores for handling cargo. Its use should be strictly confined to handling crates, cases and other similar articles, and it should never be used for handling bales, bags and other " softly " packed goods.

HATCH BEAMS—removable steel beams fitted athwart a hatch to strengthen it and to support the hatch boards.

HATCH BOARDS—stout timber boards which fit over the hatch beams and form part of the hatch cover.

HATCH SQUARE—the area enclosed by the coamings of a hatch.

HOIST OR SETT—one or a number of items of cargo slung for hoisting.

HOMOGENEOUS CARGO—a cargo comprising one commodity.

HOUSE FALL—a variation of the union purchase rig in which one of the whips is led through a head block shackled to a structure on shore. (See Fig. 135)

JUMBO DERRICK—a derrick designed for heavy lifts.

LAY DAYS—the period agreed upon between a charterer and a shipowner for loading or discharging a shipment of cargo. (See also DEMURRAGE and DESPATCH MONEY.)

LAZARET—a store-room for a ship's stores or provisions, usually situated in the after part of the ship.

LIMBER BOARDS—removable boards between the sides and bottom of a hold to give access to the bilges for cleaning or drying them out.

LIVERPOOL RIG—a rig used with a single standing derrick rigged to plumb over the ship's side. The hoist is guided through the hatch by reeving the whip through a tail block fitted with a bull-rope, the bull-rope being worked from a portable bollard clamped to the hatch coaming. (See Fig. 135 on page 438).

LOCK-UP OR LOCKER—a cargo space specially built or partitioned-off from a hold and situated usually in one of the lower or upper 'tween decks, where valuable cargo or cargo of a pilferable nature is stowed.

LOWER HOLD—the lowest of a tier of holds in ships fitted with one or more 'tween decks.

MANIFEST—a detailed list of a ship's cargo, prepared at the port of shipment ; it shows the marks, numbers and descriptions of packages, together with the names of the consignees.

MARRIED GEAR—see UNION PURCHASE.

MAST PLATFORM—see DERRICK TABLE.

MIDSHIP DERRICK—the derrick which plumbs the hatch in the UNION PURCHASE RIG. (which see)

MIDSHIP GUY—the guy rigged between the heads of the midship and outboard derricks.

NETT WEIGHT—the weight of the contents of a case or container.

OPTIONAL CARGO—cargo of a general nature which, at the option of the consignor, may be discharged at any one of a number of ports,

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OVER-CARRIAGE—the carriage of cargo beyond its port of destination due to an oversight.

OUTBOARD OR YARD-ARM DERRICK—The derrick which plumbs over the ship's side in the union purchase rig (which see).

PALLET—a wooden tray used for slinging a number of small items of cargo in one sett.

PARCEL—a number of items of cargo from a common source, or for a common destination.

PONTOON HATCH-COVER—a steel hatch-cover unsupported by beams.

PORT SPEED—the rate at which cargo is loaded or discharged at a particular port. For bulk cargo it is sometimes called " the custom of the port."

QUARTERING—timber of square cross-section used as dunnage.

RUNNER—the whip or fall of a derrick.

SAVE-ALL—a net rigged to catch any cargo falling between the ship and the quay, or a canvas sheet spread in a hold or on deck to catch any leakage from bagged cargo such as grain.

SEPARATION—the stowage of one type of cargo apart from another as a precaution against fire, and for the prevention of contamination or deterioration of the cargo and damage to the cargo or the ship.

SETT—see HOIST.

SHIPPING TON—a measurement of 40 cu. ft. used at the option of the shipowner in determining the freightage dues for cargo; it is approximately the space occupied by a ton of well-stowed Welsh coal. The freightage of heavier cargo is computed on its deadweight.

SHORT-LANDING—failure to discharge the whole of a cargo at its destination, due to an oversight. (See also OVER-CARRIAGE.)

SPARRING—planking or other material fitted as a lining to the sides or ends of a compartment to insulate the cargo from the sides or bulkheads.

SPECIAL CARGO—fragile or valuable cargo which is consigned to the special custody of the Chief Officer, and stowed usually in the locker or other secure stowage.

STANDING DERRICK—a derrick rigged to plumb one position only.

STEVEDORE—strictly, the person who contracts for the handling of cargo into or out of a ship. In general, however, men actually engaged in stowing or discharging the cargo are called stevedores.

STOWAGE FACTOR—the space occupied by a well-stowed ton (weight) of any particular type of cargo. It includes allowances for broken stowage and any dunnage required for that particular type of cargo.

STOWAGE PLAN—a rough plan of the ship showing the stowage of her cargo.

STRONG-ROOM—a strongly constructed, fire-proof compartment, provided in some ships for the stowage of very valuable cargo or specie.

SUPERCARGO—short for Cargo Superintendent—an official formerly appointed to a cargo ship by the shipowner or charterer expressly for the supervision of the loading, selling and discharging of her cargo, and obtaining other cargoes; he sailed with the ship throughout her voyage. This office is seldom if ever filled nowadays.

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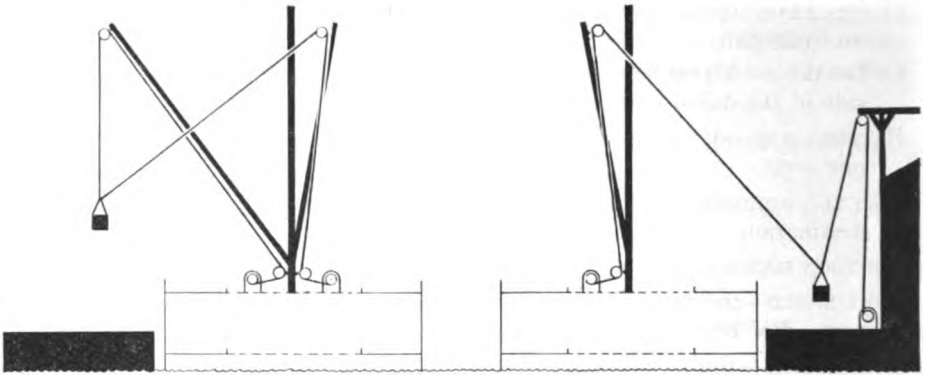
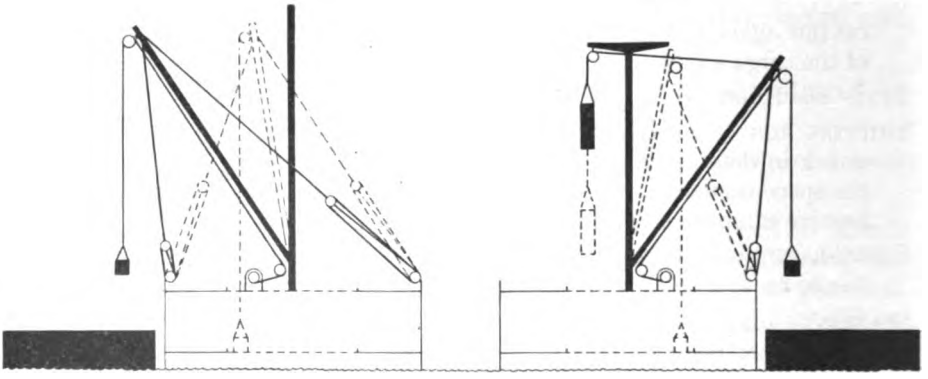


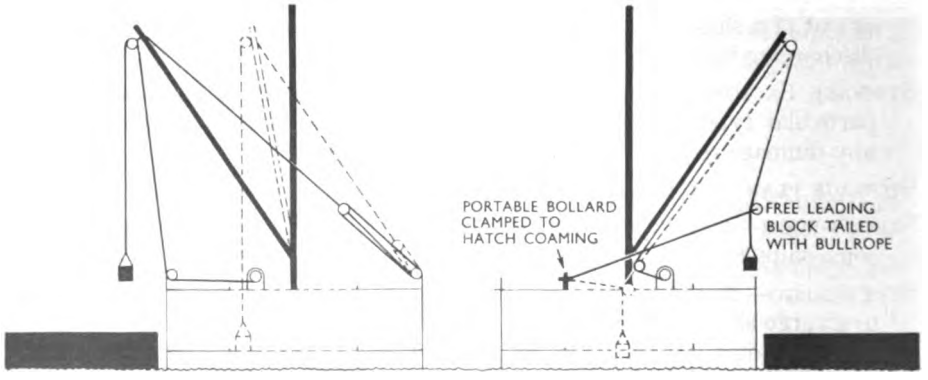
STANDING DERRICKS—UNION PURCHASE
Usual method for loading and discharging

STANDING DERRICK—HOUSE FALL
Used when one derrick and one winch only are available in ship for loading or discharging



SWINGING DERRICK
Used for loading and discharging when one derrick and one winch only are available in ship

SWINGING DERRICK WITH DEADMAN
Used for discharging—deadman returns light derrick over hold



SWINGING DERRICK WITH WING LEAD
Used for discharging—lead of runner to bulwarks swings derrick over side

STANDING DERRICK—LIVERPOOL RIG
Used for discharging—bullrope tailed to leading block used to guide hoist clear of hatchway

Fig. 135. Rigs of derricks

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SWINGING DERRICK—a derrick rigged to plumb alternately over the hold and over the ship's side (see Fig. 135).

TALLY, AND TALLY CLERK—to tally is to check each item of cargo as it is loaded or discharged, and a tally clerk is the man who does this job.

TARE WEIGHT—the weight of an empty case or vehicle.

TOMMING—shoring cargo to prevent it from shifting.

'TWEEN DECK—an auxiliary cargo deck below the upper deck. In a hold with two 'tween decks the spaces are called the upper and lower 'tween decks and the lower hold.

ULLAGE—the amount by which a cask, tank or other container holding liquid is not full.

UNION PURCHASE OR MARRIED GEAR—a rig in which the whips of two standing derricks are joined to the cargo hook. One derrick plumbs the hold and the other plumbs over the ship's side (see Fig. 135).

WHARFINGER—the owner of a wharf with certain responsibilities in regard to goods stowed thereon, the upkeep of the wharf and of the berths alongside it.

WING LEAD—an alternative to the backweight method (which see) of rigging a swinging derrick. The whip is led from the head of the derrick through a leading block on the ship's side and thence to the winch. As the whip takes the weight of a hoist the derrick will tend to swing over the ship's side (see Fig. 135).

WINGING—stowing cargo so that most of it is distributed in the wings of the hold. This may be done when stowing heavy ores to improve the seaworthiness of the ship.

Planning the Stowage of a General Cargo

The aim in planning the stowage of a shipment of cargo is to achieve the condition of full and down, but with a general cargo this is seldom possible because in doing so the planner must fulfil many different and often conflicting requirements. These requirements are: ensuring the necessary stability and trim of the ship throughout the voyage, ensuring that the cargo to be discharged at each port is easily accessible without having to restow the remainder, ensuring that it can be discharged as rapidly as possible, and seeing that those types of cargo which, owing to their nature, must not be adjacent to each other are well separated.

PROVISION OF CARGO

Most shipping lines employ agents at the major ports visited by their ships to advertise for cargo and arrange for its delivery. The shipowner advises his agents well beforehand of the dates of arrival, loading and departure of each ship and also of her destination and route, and the scheduled and optional ports of call on the voyage. The agents then advertise this information among those shippers and others who are known to be interested in the trade along the proposed route, and ask them for details of any cargo they may have for shipment. These details are forwarded by the agent to the shipowner who then starts to select the cargo and plan its stowage.

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Ships' Plans

The plans of a ship should include the following details essential to the cargo planner :—

(i) the grain and bale capacities of each hold ;
(ii) the deck areas of holds and hatch squares ;
(iii) upper deck areas available for deck cargo ;
(iv) the dimensions of hatches and the number and capabilities of the derricks ;
(v) the cargo deadweight of the ship ;
(vi) the deadweight of the ship when light, *i.e.*, with stores, fuel, fresh water, crew and ballast on board, but no cargo ;
(vii) the draughts of the ship in the light condition ;
(viii) the draughts of the ship when she is loaded to her maximum permissible seasonal draught ;
(ix) stability data, such as cross curves of stability, hydrostatic curves and trim tables.

Particulars of Cargo

The details of each item of cargo, or of a parcel of similar items, should include :—

(i) the overall dimensions and nett weight of each item ;
(ii) the number of packages of the same nature in any one parcel ;
(iii) the consignor's and consignee's names and addresses ;
(iv) the marking on each item or batch.

Dunnage

The kind, quantity and total weight of dunnage carried will vary considerably with the nature of the cargo carried. If particularly heavy items are to be stowed in the 'tween decks, or as deck cargo, the decks may have to be shored from the lower hold upwards and each item may require a considerable amount of tomming. Sometimes a temporary 'tween deck may have to be built in a deep lower hold when heavy cargo has to be stowed over crushable cargo, or a temporary bulkhead may have to be built to separate bulk cargo from general cargo. Bins may have to be constructed to protect deck cargo, and if there is much of it catwalks may have to be built over it to give access forward and aft.

These are, however, exceptional cases, and the dunnage usually consists of baulks, planks, and quarterings of timber, cordwood, matting, cloths and rope, amounting in all to between about 100 and 200 tons deadweight in a ship of 7,000 tons gross.

The dunnage deadweight must of course be subtracted from that of the ship's cargo when assessing the cargo deadweight available, and similarly an allowance must be made for it when assessing the ship's available cargo capacity.

Broken Stowage

The stowage factor for any particular type of cargo includes an allowance for broken stowage, but this allowance applies to that type of cargo alone and does not allow for broken stowage which may result from stowing that particular cargo with other kinds of cargo in the same hold. An allowance must also be made for broken stowage due to the shape of the holds and to pillars

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and similar fittings in way of the cargo. Furthermore the stowage factor for a particular cargo may vary from port to port according to the way in which it is packed and the way in which it is stowed by the local stevedores. The planner must therefore make an arbitrary allowance for broken stowage, based on his experience of the various kinds of cargo and the skill of the stevedores at a port. This allowance may vary from 10 per cent to as much as 25 per cent of a ship's bale capacity.

The following examples show the wide differences between the stowage factors of different types of cargo :—

COMMODITY	PACKAGING	STOWAGE FACTOR
Antimony	cases	20
Bran	bags	100–130
,,	bales	80–85
Cotton	bales	50–135
Granite	blocks	16–18
Hay	bales	90–105
Pig-iron	ingots	12–15
Rubber	cases	65–70
,,	bags or bales	40–50
Sugar	bags	40–50
Tea	chests	96–120
Tin	ingots	8–10
Tinned fruit	cases	60
Tyres	loose or bales	140–200
Wool	bales	40–240

SEPARATION

The segregation of cargo is necessary to prevent one kind from contaminating or damaging another, to minimise the risk of fire or explosion, to ensure that the ship has the required degree of stability, to provide necessary ventilation, to ensure the accessibility of cargo at its port of discharge, to avoid having to restow cargo, and to ensure that it can be discharged quickly and efficiently.

Contamination and Tainting.—Some commodities are very susceptible to tainting by moisture or odours, and others are very liable to leak or to produce moisture, odours, or noxious gases. Examples of the former are flour, sugar, eggs, cheese, tea and pepper, and examples of the latter are potatoes, onions, green vegetables, fruit, wine, grain, wet hides, manure, copra, and freshly sawn timber. Other goods are liable to be damaged or to deteriorate if placed in contact with certain other goods, or even near them, examples being iron and bagged chemicals, cotton and rubber, cotton and coke, cotton and oil, and chrome and manganese ores. Yet other commodities are susceptible to spontaneous combustion if not properly ventilated, and some will produce moisture or noxious vapours if placed next to a hot bulkhead such as that of a boiler-room or engine-room, examples being copra, nuts, hay, wool, and grain.

Some of these goods can be carried in the same hold if separated by stowing dry goods over wet goods, or by stowing them at opposite ends of a hold, or some in the 'tween decks and others in the lower hold. Some kinds of cargo, however, must be stowed in different holds, and in rare cases they may have to be stowed at opposite ends of the ship, examples being frozen meat and fruit, and explosives of different types.

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Crushing and Chafing.—Fragile goods may be crushed if overstowed with heavy cargo, or if stowed in too many tiers without separating them with dunnage, or if there is insufficient vertical separation with dunnage so that cargo in the wings is crushed as the ship rolls. Chafing is caused chiefly by bad stowing which allows adjacent items of cargo to rub against each other with the movement of the ship. All of these, except overstowing, are mainly the concern of the stevedores and the ship's officers, but the planner can assist to a certain extent by providing what is called "filler cargo," consisting of small packages of suitable goods which can be stowed between largely different kinds of cargo, and so enable the holds to be stowed compactly, symmetrically and evenly. Examples of filler cargo are bones, cordwood, bundles of wood and matting, rubber tyres, and coconut husks; such goods are usually accepted at a lower rate of freight on the understanding that they may be used as filler cargo, but on no account should they be used as dunnage to chock or separate the cargo.

Dangerous Goods.—Some explosive, highly inflammable, or corrosive goods are classed as "dangerous goods" and their stowage is regulated by law. Many kinds of dangerous goods must be carried as deck cargo and be stowed apart from each other in places where any fumes from them will not be drawn into the holds or living quarters, examples being drums of acid and cylinders of compressed, inflammable gases. Other goods, such as explosives, fireworks and matches, may be stowed below but in specially built, well-ventilated magazines, or in the 'tween decks well clear of other cargo. Other goods of this nature, such as cased oil and petroleum products in drums, may be stowed in the lower holds, but special precautions must be taken to provide adequate ventilation and a cool temperature. Precautions must also be taken against fire or explosion *after* dangerous goods have been discharged.

Stability and Trim.—Separation of the cargo to provide the required degree of stability and trim both at the start of and throughout a voyage is most important. Account must be taken of the consumption of fuel, stores and water between ports of call, the discharge of part cargoes at intermediate ports of call, and sometimes the minimum depths of water which the ship may encounter at any port. Whenever possible the stowage should be arranged so that the ship will have the required degree of stability between one port and the next without having to take in, or discharge, ballast while at sea, any necessary ballasting being carried out before the ship sails or while she is in sheltered waters. This is important because many losses have been attributed to attempts to improve a ship's stability by ballasting while she was in a seaway.

If a ship is filled to capacity with a general cargo entirely for one destination and if the stowage factors of the different types of cargo are not unduly high or low and the ship is not unduly stiff or tender, the shape and size of her holds and the necessity for stowing light cargo over heavy cargo will usually ensure that on sailing she will have the required degree of buoyancy, stability and trim. If, however, the ship is bound for several intermediate ports of call, the various part cargoes must be distributed throughout the holds and stowed symmetrically, both fore and aft and athwartships. If some of the cargo is particularly heavy, it must be distributed among the holds to avoid any undue shearing stresses, and also be divided between the lower holds and the 'tween decks so that the ship is neither too stiff nor too tender (see Chapter XVIII

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"Ship Stability" pages 407 to 417). Care should be taken, however, never to overload the 'tween decks.

Many British ships are provided with a Ralston's "Stability Indicator." This is virtually a pivoted model of the ship which, when weights representing the deadweight of the cargo are added, shows the stability, draught and trim of the ship when loaded.

Accessibility.—It is essential that cargo should be readily accessible on arrival at the port of its destination so that there will be no delay in discharging it, and no wasted time and expense in having to restow any other cargo which may be in the way. Cargo is usually stowed in the reverse order to that in which it will be discharged, and this reduces the possibility of overstowing a cargo destined for an early port with the cargo consigned to a later port. The 'tween decks and hatch squares are very useful for separating cargo for purposes of accessibility, but the hatch square of the upper 'tween decks should always be reserved for cargo destined for the first port of call.

Optional cargo consigned for discharge at two or more ports is the most difficult to stow in this respect, particularly if there are several parcels of it. One way of dealing with it is to stow it in the upper 'tween decks in blocks spaced apart from one another, each reaching from the hatch square to the ends or the wings or the bulkheads of the 'tween deck.

Speed of Handling.—The planner must ensure that the cargo is stowed so that it can be discharged as quickly as possible. Any large quantity of cargo destined for a particular port should therefore be distributed evenly among as many holds as is practicable, so that each hold can be used simultaneously when loading or discharging. For the same reason the cargo should be stowed at the opposite ends or sides of each hold so that two gangs of stevedores can work in the hold at the same time without getting in each other's way.

When two or more cargoes each destined for a different port are stowed together in the same hold their stowage must be arranged so that discharging one will not necessitate restowing the remainder. The stowage of such cargoes should therefore be stepped down so that if one or more is discharged the remainder is stable and can easily be prevented from shifting with dunnage.

Examples of good and bad stowage are shown in Fig. 136, and explained in the following notes.

(i) In No. 1 hold cargo for the second and third ports has been stowed in the 'tween deck at the opposite end to its counterpart in the lower hold, thus enabling it to be discharged by two gangs working simultaneously. In No. 2 hold this would not be possible.

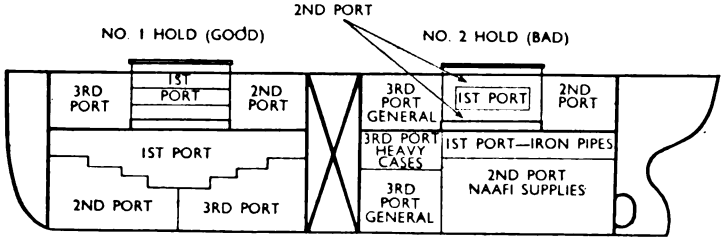

Fig. 136. Correct and incorrect methods of stowage

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(ii) In No. 1 hold cargo for the second and third ports has been stepped down to avoid having to restow it after discharging the cargo for the first and second ports. In No. 2 hold cargo for the third port would have to be restowed after cargo for the first and second ports had been discharged.

(iii) In No. 2 hold it will be very difficult to handle the heavy cases when discharging them because of their stowage position. These should have been stowed at the bottom of the hold where they would be dealt with last of all.

(iv) In No. 2 hold the N.A.A.F.I. supplies, which are not usually of a robust nature, have been overstowed by heavy iron pipes which will probably crush them.

STAGES IN PLANNING

Capabilities of the Ship.—The first stage in planning a stowage is to consider the features and capabilities of the ship and tabulate them in detail thus :—

Deadweight :—		
light ship	...	2,476 tons
fuel	...	1,246 ,,
fresh water	...	320 ,,
stores	...	190 ,,
ballast	...	150 ,,
dunnage, say	...	100 ,,
departure state	...	3,482 tons
maximum seasonal displacement		10,725 tons
maximum cargo deadweight		7,243 tons
Bale capacity :—		
locker under forecastle	...	8,000 cu. ft.
No. 1 hold—'tween deck	...	22,830 ,, ,,
—lower hold	...	51,110 ,, ,,
No. 2 hold—'tween deck	...	37,030 ,, ,,
—lower hold	...	74,610 ,, ,,
No. 3 hold—'tween deck	...	30,930 ,, ,,
—lower hold	...	58,010 ,, ,,
No. 4 hold—'tween deck	...	27,100 ,, ,,
—lower hold	...	52,440 ,, ,,
Total under-deck stowage	...	362,060 cu. ft.

Deck stowage (*estimated*) :—
deadweight : 100 tons ; capacity : 30,000 cu. ft.

Stowage factors :—

under-deck : $\frac{\text{bale capacity}}{\text{cargo deadweight, less dunnage}} = \frac{362,060}{7,143} = 50{\cdot}7$

full and down : $\frac{\text{total capacity}}{\text{total cargo deadweight}} = \frac{392,060}{7,243} = 54{\cdot}1$

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Operational data :—
normal full speed : 11 knots ;
average daily consumptions :—
fuel : 13 tons ;
fresh water : 5 tons ;
stores : ½ ton.

Draughts :—
before loading :—forward : 10 ft. 4 in.;
aft : 15 ft. 8 in.;
mean : 13 ft. 0 in.;
maximum seasonal : 26 ft. 3 in.

Derricks and hatches :—
four hatches, each 20 ft. × 30 ft. ;
eight 5-ton derricks, two to each hatch, maximum load 30 cwt. when rigged with single whip ;
two jumbo derricks :—No. 2 hold : 30-ton,
No. 3 hold : 15-ton.

Special stowages :—
strong room, capacity 1,000 cu. ft.

Break-down of Cargo.—The second stage is to tabulate the shipment under the headings of deadweight and capacity, heavy cargo, fragile cargo, filler cargo, optional cargo, special cargo, dangerous goods, deck cargo, cargo requiring special separation, heavy lifts, and ports of loading and discharging.

In the deadweight and capacity table the total deadweight, cubic capacity, and stowage factor of each type of cargo are entered in columns from which the total deadweight and capacity of the shipment, and its average stowage factor can be obtained. By comparing these figures with the cargo deadweight, the stowage capacity and the stowage factor of the ship, it can be seen whether she can take the whole shipment, and if so the amount which can be stowed below, the amount which must be carried as deck cargo, and any broken stowage.

Suppose, for example, a shipment with a deadweight of 6,300 tons, a capacity of 350,000 cu. ft., and an average stowage factor of 56 is required to be loaded in the ship whose particulars have just been given. At first glance it would appear that the whole shipment could be stowed below, but an allowance must be made for broken stowage ; assuming this to be 10 per cent of the ship's bale capacity the available capacity will be reduced to 325,854 cu. ft. and therefore some 24,000 cu. ft. must be carried as deck cargo.

The tables of heavy, fragile and filler cargoes will enable a rough plan of the stowage to be made, having regard to the requirements of stability, trim, stresses and separation ; and items suitable for deck cargo, some of which may comprise dangerous goods, can be selected. Optional cargo, of which there is not usually a large amount, will probably be stowed in an upper 'tween deck, and special cargo in the locker.

The table of heavy lifts should show those items of cargo which alone weigh more than a derrick is capable of hoisting when rigged with a single whip, and special arrangements must be made for any which are beyond the capabilities of the ship's derricks. In a large port most of the heavy lifts are usually loaded by dockside and floating cranes.

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The table of ports of loading and discharging will show in what order the cargo should be loaded and enable the planner to arrange the dates of delivery alongside the ship of each batch of cargo.

At this stage a rough check can be made of the effect of the general distribution of the cargo on the stability and trim of the ship.

Stowage Plan.—The third stage is to make out a detailed plan of the stowage. Such plans show a sectional elevation of the ship in an exaggerated and much simplified form, and some also include deck plans and cross-sections of the holds. The details usually comprise the total deadweight in each hold, heavy lifts, deck cargo, special cargo, livestock if any, the ship's particulars, (such as her draughts, freeboard, dimensions, bunkers, metacentric height) and ports of loading and discharging. It is also usual to include the metacentric height for the worst possible condition of the ship during her voyage, that is with her fuel and water nearly exhausted, giving her two slack tanks and an otherwise empty double bottom.

An actual stowage plan for the S.S. *Clan Maclennan* of the Clan Line, homeward bound from India and Ceylon to the United Kingdom and the Continent, with five ports of loading and five of discharging, is reproduced in Fig. 137 by kind permission of the managers, Messrs. Cayzer, Irvine and Co. Ltd. She is an open, shelter-deck type of ship, and approximately eight feet should therefore be added to the freeboards shown in the plan to give the actual freeboard up to the upper deck. A detailed study of this plan will show how the various stowage requirements just enumerated have been met (see page 447).

When the plan is completed, as accurate an estimate as possible must be made of the effects of the loading and discharge of cargo on the stability and trim of the ship, and the plan must be adjusted as necessary. Copies of the plan and the cargo manifest are then sent to the stevedoring firms, to the Company's agents at the various ports of call, to the head offices of the Company if it has been made out in the ship or abroad, and to the master of the ship if it has been made out in the Company's offices.

It should be borne in mind that the initial plan, usually called a " pro forma," may be subject to considerable revision after it is made out initially. The stevedoring firms may require minor alterations to suit the handling of particular types of cargo or to comply with certain conditions of labour, some cargo may be delayed in transit, some cancelled, and some added, and finally the Master, who is ultimately responsible for both his ship and her cargo and who therefore has the last say in the matter, may require some adjustments to suit any peculiarities or features of his ship.

Loading Organisation.—The fourth and final stage in planning is to estimate the time required to load the cargo, fix the provisional date of sailing, arrange the fuelling, storing and watering of the ship and her arrival at her loading berth, and to arrange the delivery of the cargo to fit in with the loading schedule.

Port speed at one port may vary considerably from that at another because it depends largely on the skill of the stevedores, the hours of work and other conditions of labour, and in the same port one gang of stevedores may work much better than another. Knowledge of local capabilities and conditions is therefore of great value when estimating the time required for loading or discharging a cargo. Port speed will also depend upon the type of cargo being handled; cargo made up of small, light packages usually takes longer to load or discharge than heavy cargo or large items such as trucks. For a general cargo,

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Fig. 137.
EXAMPLE OF A
GENERAL CARGO STOWAGE PLAN

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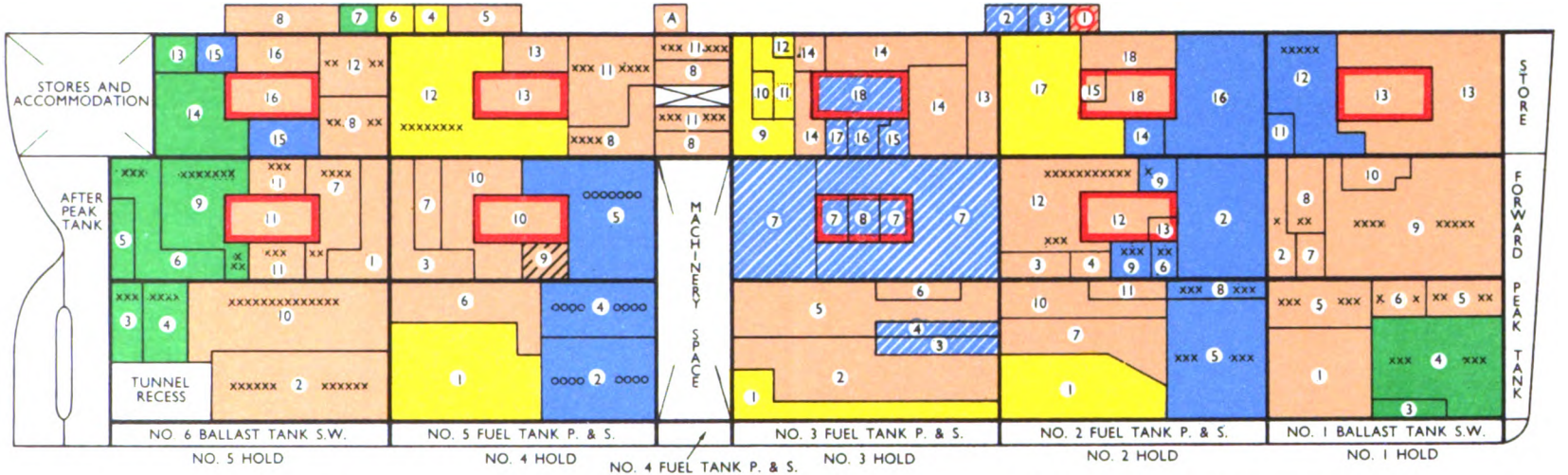

S.S. CLAN MACLENNAN—SHIP'S PARTICULARS

PORT		DRAUGHTS FORD.	AFT.	MEAN	FREE-BOARD	G.M.	BALLAST F.P.T.	NO.1	NO.6	A.P.T.
MORMAGOA	ARR.	10' 6"	16'0"	13'3"	16' 2½"	5·9'	F.W. 125 TONS	S.W. 112 T.	NIL	NIL
	DEP.	14' 1"	19'5"	16'9"	12' 8½"	7·0'	F.W. 125 T.	S.W. 112 T.	NIL	NIL
KOZHIKODE	ARR.	12'10"	20'4"	16'7"	12'10½"	6·9'	NIL	NIL	NIL	NIL
	DEP.	13' 9"	21'2"	17'5½"	12' 0"	5·4'	NIL	NIL	NIL	NIL
COCHIN	ARR.	13' 9"	21'2"	17'5½"	12' 0"	5·4'	NIL	NIL	NIL	NIL
	DEP.	17' 3"	23'3"	20'3"	9' 2½"	5·6'	F.W. 125 T.	NIL	NIL	F.W. 60 T.
ALLEPPEY	ARR.	17' 3"	23'3"	20'3"	9' 2½"	5·6'	F.W. 125 T.	NIL	NIL	F.W. 60 T.
	DEP.	19' 7"	23'5"	21'6"	7'11½"	5·4'	F.W. 125 T.	NIL	NIL	NIL
GALLE	ARR.	19'10"	23'0"	21'5"	8' 0½"	5·4'	F.W. 125 T.	NIL	NIL	NIL
	DEP.	25' 6"	26'0"	25'9"	3' 8½"	3·8'	F.W. 125 T.	NIL	NIL	F.W. 50 T.
SUMMER SEASONAL		26'0½"	26'0½"	26'0½"	3' 4½"	MAX. DISPL.		13,641 T.		
BUNKERS		526	FRESH WATER: BOILERS—420 T. DOMESTIC—120 T.							

WORST CONDITION FUEL AND WATER IN D.B. NEARLY EXHAUSTED G.M. +2·7'

CARGO KEY

PORTS OF DISCHARGE	
	PORT SAID
	LONDON
	ANTWERP
	HAMBURG
	GLASGOW
	PORT SAID OPTIONAL LONDON
	LONDON OPTIONAL HAMBURG
OOO	DHOLLS FOR HAMBURG
XXX	DHOLLS FOR GLASGOW
	CARGO ON TWEEN DECK HATCH SQUARES

DISPOSITION OF CARGO DEADWEIGHT ON DEPARTURE

COMPARTMENT	MORMAGOA	KOZHIKODE	COCHIN	ALLEPPEY	GALLE	TOTALS
NO. 1 L/HOLD		94	108			202
NO. 1 L/TWEEN		20	123			143
NO. 1 U/TWEEN			4		171	175
NO. 2 L/HOLD	1,203		294	275		1,772
NO. 2 L/TWEEN		136	22	234		392
NO. 2 U/TWEEN				54	441	495
NO. 3 L/HOLD			89	17	746	852
NO. 3 L/TWEEN					583	583
NO. 3 U/TWEEN		105	63	21	174	363
NO. 4 L/HOLD	797	125	230			1,152
NO. 4 L/TWEEN		75	94	93		262
NO. 4 U/TWEEN		1	42	90	354	487
NO. 5 L/HOLD		33	107	48		188
NO. 5 L/TWEEN			86	63		149
NO. 5 U/TWEEN			38	13	111	162
ON DECK			20		20	40
TOTALS	2,000	589	1,320	908	2,600	7,417

STOWAGE PLAN — S.S. CLAN MACLENNAN FROM: INDIA AND CEYLON TO UNITED KINGDOM AND CONTINENT. MORMAGOA, KOZHIKODE, COCHIN, ALLEPPEY & GALLE TO PORT SAID, LONDON, ANTWERP, HAMBURG & GLASGOW

(For Key to Details of Cargo see opposite page)

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KEY TO STOWAGE PLAN OF S.S. "CLAN MACLENNAN"

NO. 5 HOLD

PLAN NO.	COMMODITY	QUANTITY	WT TONS	LOADING PORT
1	PEPPER	538 BAGS	33	KOZHIKODE
2	COIR YARN (ROTTERDAM)	250 BALES	40	COCHIN
3	CASHEW KERNELS	150 CASES	5	COCHIN
4	NUX VOMICA	946 BAGS	60	COCHIN
5	PERSONAL EFFECTS	7 CASES	1	COCHIN
5	MATS & MATTING	21 PKGS	1	COCHIN
6	NUX VOMICA	654 BAGS	42	COCHIN
7	PEPPER	680 BAGS	41	COCHIN
8	GLYCERINE (ROTTERDAM)	40 DRUMS	10	COCHIN
8	CHAULMOOGRA OIL	56 CASES	2	COCHIN
8	NUX VOMICA	400 BAGS	25	COCHIN
9	COIR YARN	10 BALES	2	ALLEPPEY
9	MATS & MATTING	570 PKGS	29	ALLEPPEY
10	MATS & MATTING	760 PKGS	48	ALLEPPEY
11	MATS & MATTING	605 PKGS	32	ALLEPPEY
12	MATS & MATTING	189 PKGS	11	ALLEPPEY
13	MATS & MATTING	10 PKGS	1	ALLEPPEY
14	RUBBER	450 BALES	50	GALLE
15	RUBBER	460 BALES	51	GALLE
16	RUBBER	931 BALES	110	GALLE
X	COIR YARN	3,780 DHOLLS	4	COCHIN

SHIP'S OFFICE

A	CINNAMON BARK OIL	1 CASE	—	GALLE

NO. 4 HOLD

PLAN NO.	COMMODITY	QUANTITY	WT TONS	LOADING PORT
1	MANGANESE ORE	IN BULK	797	MORMAGOA
2	COIR YARN	763 BALES	120	KOZHIKODE
2	PALMYRA FIBRE	13 BALES	2	KOZHIKODE
3	COIR YARN	449 BALES	73	KOZHIKODE
4	COIR YARN	407 BALES	65	COCHIN
5	COIR YARN	562 BALES	89	COCHIN
6	CASHEW KERNELS	5,636 CASES	165	COCHIN
7	CASHEW KERNELS	165 CASES	5	COCHIN
8	MATS & MATTING	552 PKGS.	30	COCHIN
8	PERSONAL EFFECTS	5 CASES	1	KOZHIKODE
9	COIR YARN	50 BALES	9	ALLEPPEY
10	COIR YARN	4 BALES	1	ALLEPPEY
10	MATS & MATTING	1,388 PKGS	83	ALLEPPEY
11	MATS & MATTING	1,561 PKGS	90	ALLEPPEY
12	POONAC	4,482 BAGS	224	GALLE
13	RUBBER	1,119 BALES	130	GALLE
O	COIR YARN	1,980 DHOLLS	5	KOZHIKODE
X	COIR YARN	5,800 DHOLLS	12	COCHIN

NO. 3 HOLD (contd.)

16	PEPPER (MARSEILLES)	64 BAGS	4	COCHIN
17	COIR YARN (GENOA)	50 BALES	9	ALLEPPEY
18	RUBBER	478 BALES	54	GALLE
—	COCONUT HUSKS	—	98	GALLE
X	COIR YARN	200 DHOLLS	1	COCHIN

NO. 3 HOLD

PLAN NO.	COMMODITY	QUANTITY	WT TONS	LOADING PORT
1	COCONUT OIL	301 DRUMS	155	GALLE
2	COCONUT OIL	829 DRUMS	420	GALLE
3	COCONUT OIL	107 DRUMS	60	GALLE
4	COIR YARN	160 BALES	25	COCHIN
5	MATS & MATTING	1,142 PKGS	64	COCHIN
5	MATS & MATTING	218 PKGS	17	ALLEPPEY
6	COIR NET BAGS	44 BALES	5	GALLE
6	COIR YARN	75 COILS	8	GALLE
7	COCONUT OIL	1,069 DRUMS	550	GALLE
8	RUBBER	287 BALES	33	GALLE
9	COIR YARN	302 BALES	48	KOZHIKODE
10	COTTON YARN	112 BALES	20	COCHIN
10	COIR YARN	25 BALES	4	COCHIN
10	PEPPER	16 BAGS	1	COCHIN
11	COIR YARN	70 BALES	13	ALLEPPEY
11	MATS & MATTING	57 PKGS.	1	ALLEPPEY
12	RUBBER	135 BALES	15	GALLE
13	COTTON YARN (MONTEVIDEO)	50 CASES	6	COCHIN
14	COIR YARN	343 BALES	62	GALLE
14	RUBBER	268 BALES	35	GALLE
14	CINNAMON	25 BALES	1	GALLE
14	COIR YARN	75 COILS	7	GALLE
15	COIR YARN (MARSEILLES)	306 BALES	49	KOZHIKODE
15	COIR YARN (TRIPOLI)	25 BALES	3	KOZHIKODE
15	PEPPER (GENOA)	80 BAGS	5	KOZHIKODE
16	COIR YARN	170 BALES	27	COCHIN

NO. 2 HOLD

PLAN NO.	COMMODITY	QUANTITY	WT TONS	LOADING PORT
1	MANGANESE ORE	IN BULK	1,203	MORMAGOA
2	COIR YARN	545 BALES	89	KOZHIKODE
2	PEPPER	59 BAGS	4	KOZHIKODE
3	COIR YARN	75 BALES	13	KOZHIKODE
3	PALMYRA FIBRE	67 BALES	10	KOZHIKODE
4	ROSEWOOD (LE HAVRE)	19 LOGS	20	KOZHIKODE
5	COIR YARN	1,356 BALES	217	COCHIN
6	PEPPER	251 BAGS	16	COCHIN
7	COIR YARN	464 BALES	74	COCHIN
8	COIR YARN	271 BALES	43	ALLEPPEY
9	COIR YARN	630 BALES	100	ALLEPPEY
10	COIR YARN	1,259 BALES	220	ALLEPPEY
11	MATS & MATTING	544 PKGS.	12	ALLEPPEY
12	MATS & MATTING	2,200 PKGS.	122	ALLEPPEY
13	CASHEW KERNELS	275 CASES	12	ALLEPPEY
14	COIR YARN	329 BALES	53	ALLEPPEY
15	MATS & MATTING	31 PKGS.	1	ALLEPPEY
16	COIR YARN	652 BALES	130	GALLE
17	POONAC	3,018 BAGS	151	GALLE
18	RUBBER	1,387 BALES	160	GALLE
X	COIR YARN	5,480 DHOLLS	9	COCHIN

NO. 1 HOLD

PLAN NO.	COMMODITY	QUANTITY	WT TONS	LOADING PORT
1	TEA	1,796 CHESTS	92	KOZHIKODE
2	TEA	414 CHESTS	20	KOZHIKODE
3	COIR YARN	13 BALES	2	KOZHIKODE
4	COIR YARN	275 BALES	44	COCHIN
5	TEA	1,035 CHESTS	56	COCHIN
6	MATS & MATTING	85 PKGS.	5	COCHIN
7	TEA	135 CHESTS	6	COCHIN
8	TEA	183 CHESTS	12	COCHIN
9	COIR YARN	610 BALES	95	COCHIN
10	MATS & MATTING	123 PKGS.	7	COCHIN
11	TEA	71 CHESTS	3	COCHIN
12	COIR YARN	343 BALES	68	GALLE
13	COIR YARN	479 BALES	93	GALLE
13	COIR NET BAGS	101 BALES	10	GALLE
X	COIR YARN	4,000 DHOLLS	7	COCHIN

ON DECK

1	LEMON GRASS OIL	8 DRUMS	2	COCHIN
2	LEMON GRASS OIL	18 DRUMS	5	COCHIN
3	CITRONELLA OIL	19 DRUMS	3	GALLE
4	LEMON GRASS OIL	4 DRUMS	1	COCHIN
5	LEMON GRASS OIL	63 DRUMS	12	COCHIN
6	CITRONELLA OIL	14 DRUMS	2	GALLE
7	CITRONELLA OIL	6 DRUMS	1	GALLE
8	CITRONELLA OIL	84 DRUMS	14	GALLE

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however, an average rate of 10 tons per hour per gang, working an eight-hour day on general cargo, can be taken as a basic guide.

Taking the port speed as the basis of computation, and assuming that the loading schedule has been arranged to employ all hatches simultaneously, the following example shows how a rough estimate can be made of the time required to load the ship.

Example.—A total of 1,560 tons deadweight of cargo is to be loaded into a ship with four holds, and distributed as follows :—No. 1 hold—400 tons, No. 2 hold—480 tons, No. 3 hold—320 tons, and No. 4 hold—360 tons. Four gangs are employed, one to each hold and each working an eight-hour shift. Assuming the port speed is 10 tons per hour per gang, how long will it take to load the ship ?

First find the total hours and the number of days required for each hold, thus :—

HOLD	CARGO DEADWEIGHT	TOTAL HOURS AT 10 T.P.H.	DAYS AT 8 HOURS PER DAY
No. 1... ...	400	40	5
No. 2... ...	480	48	6
No. 3... ...	320	32	4
No. 4... ...	360	36	4½

It will be seen that sailing is being delayed by Nos. 1 and 2 holds and, if port facilities allow, it might be advantageous to employ an extra shift of four hours on No. 1 hold, and extra shifts of 8 hours and 4 hours on No. 2 hold, thus reducing the loading time to 4½ days for all holds.

The loading rate of 10 tons an hour is a fair average, and in practice it will be found that the actual rate will be faster than the port speed at the beginning of the operation and then become progressively slower as the holds fill up, until at the end it will be much slower than the port speed. This is because it is easier to work in an empty or partially filled hold than in a nearly full one, and the lower tiers of cargo are usually of a heavy or robust nature which can be loaded at a greater rate than fragile or filler cargoes.

An allowance must also be made for the weather ; some cargoes cannot be loaded or discharged in wet weather, and some dangerous goods must not be handled during a thunderstorm.

The loading schedule must be carefully planned to ensure that the cargo is delivered alongside, either on the quay or in lighters, at the time ordered for its loading so as to avoid any delays or congestion. A special schedule should be made out for heavy lifts, particularly those which have to be handled by cranes.

Remarks on Stowing a General Cargo

It is not intended here to give a detailed description of the various methods of handling, slinging and hoisting cargo, because the experienced seaman has a good knowledge of the principles involved, and their application is a matter of common sense. Some notes are given, however, on the duties of a gang of stevedores, and the measurement, marking and methods of stowing general cargo.

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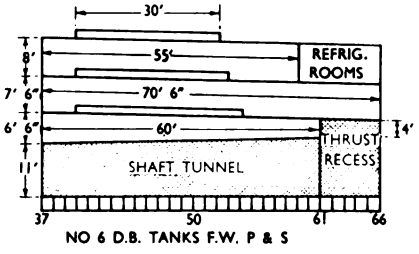
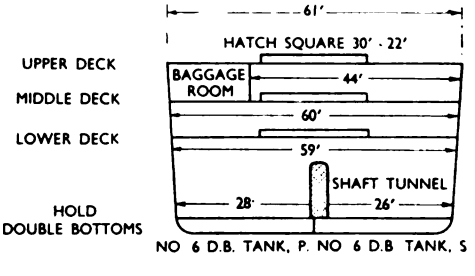
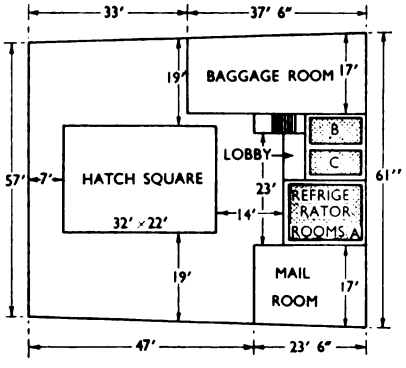
No. 4 HOLD—CARGO PLANS



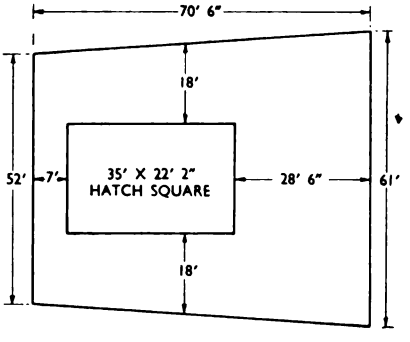
Sectional elevation through centre-line.



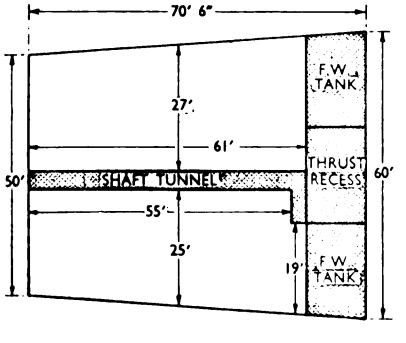
Cross section at No. 50 frame.



Plan of upper 'tween deck.



Plan of lower 'tween deck.



Plan of hold.

COMPARTMENT	FRAMES	GRAIN Cu.ft.	BALE Cu.ft.
LOWER HOLD	38-61	41,800	
LOWER 'TWEEN DECK	38-66	33,970	
UPPER 'TWEEN DECK	38-59	24,020	
HOLD TOTAL		99,790	88,270
MAIL ROOM	56-66,S.		3,100
BAGGAGE ROOM	50-66,P.		4,890
TOTAL BAGGAGE AND MAIL			7,990
REFRIGERATOR ROOM, STARB.	56-66		1,090
REFRIGERATOR ROOM, CENTRE	61-66		540
REFRIGERATOR ROOM, PORT	61-66		300
TOTAL REFRIGERATOR CARGO			1,930

Fig. 138. Example of plan of cargo hold

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Composition of a Gang

The composition of a gang of stevedores varies at different ports and with different types of cargo and ship, but the average gang employed in British ports at each hold of an ocean-going cargo liner comprises the following :—

Gang Foreman.—He is in general charge of the gang, and should have a thorough knowledge of stevedoring. His station is on deck beside the upper hatch when discharging cargo, and in the hold when loading.

Hatchwayman.—When loading cargo his station is on deck beside the upper hatch, and he is responsible for seeing that the cargo is lowered safely into the hold. When discharging cargo his place is taken by the Gang Foreman.

Winchmen.—These work the derrick winches under the orders of the Gang Foreman or the Hatchwayman, and there are one or two to each gang depending on the derrick rig in use.

Stevedores.—Eight stevedores usually work in the hold and six on the quayside or in the lighter.

In addition there are a Tally Clerk who tallies each item of cargo as it is loaded or discharged, and a Checker who measures the cubic capacity of separate items or batches of cargo ; they are usually provided by the shipowner or the stevedoring firm. There are also the men who place or remove the cargo at the loading or discharging dumps.

Measurement of Cargo

Cargo is measured for two reasons : to decide whether its freight charges will be levied on a basis of deadweight or of cubic capacity, and secondly to ascertain the approximate space it will occupy when stowed. Freightage on cargo which stows at less than 40 cubic feet to the ton is usually charged by deadweight, and other cargo by cubic capacity. The cubic capacity of an irregularly shaped item of cargo is measured as if it were exactly contained in a box of regular shape, and its measurement is therefore the product of its maximum length, breadth and height. The measurement of a cylindrical or circular object, such as a drum or tyre, would be the product of its length or breadth and the square of its diameter.

Most items of cargo are marked by the manufacturer or consignee with their net weight and dimensions, but these are usually checked at the wharf before loading.

Marking of Cargo

Most items of cargo are marked by the manufacturer or consignee to indicate their origin, destination and sometimes their nature. Some dangerous cargoes must by law be painted red or pink, or labelled " Dangerous." This system of marking, however, is used only to identify specific items of cargo before they are loaded or after they are discharged, and is of little use to distinguish one batch of cargo from another when stowed in a hold.

The clear designation of cargo destined for different ports, and sometimes of batches destined for the same port, is essential for its quick discharge and to avoid over-carriage and short-landing. Ships' officers usually devise their own code for this purpose, consisting of colours and designs to distinguish the different consignments. A code in general use is to allot a colour for each port

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of discharge and a shape such as a square, a circle, a diamond or a cross for particular batches. These designs are sometimes stencilled on each item (or on the boundary items of each parcel) as it is stowed. Other means of distinguishing one cargo from another are by tarpaulins, matting, old rope, and water paints.

Remarks on Stowage and the Use of Dunnage

The correct method of stowing a cargo and the efficient and economical use of dunnage is largely a matter of experience and common sense, and the following remarks are intended only as a general guide.

Hold Plans.—A plan of each hold is usually included in a ship's plans, but the details given are only of a very general nature and seldom include exact measurements of the actual deck areas or bale capacities available. Most ships' officers therefore make out their own plans on the lines shown in Fig. 138 to show the deck areas available, any obstructions, such as pillars and shaft tunnels, and the actual bale capacity of each hold taking into account the shape of the hold, and all obstructions to stowage within it. Such plans may subsequently be corrected as the result of experience gained in stowing various types of cargo.

Bottom and Side Dunnage.—If bottom dunnage has to be laid beneath a batch of cargo, as when a hold is not fitted with a permanent ceiling or when extra ventilation space is required beneath a cargo, the planking should be laid forward and aft over athwartship bearers to allow any moisture from the cargo or sweat from the bulkheads to run across to the limber holes in the wings and so down to the bilges.

When no cargo battens or sparring are fitted, planking should be lashed horizontally across the hold frames or held in place by upright quartering secured by wedges.

Methods of Stowing.—The general rule in stowing is to start in the wings and ends of a hold and work towards its centre, and when discharging to work

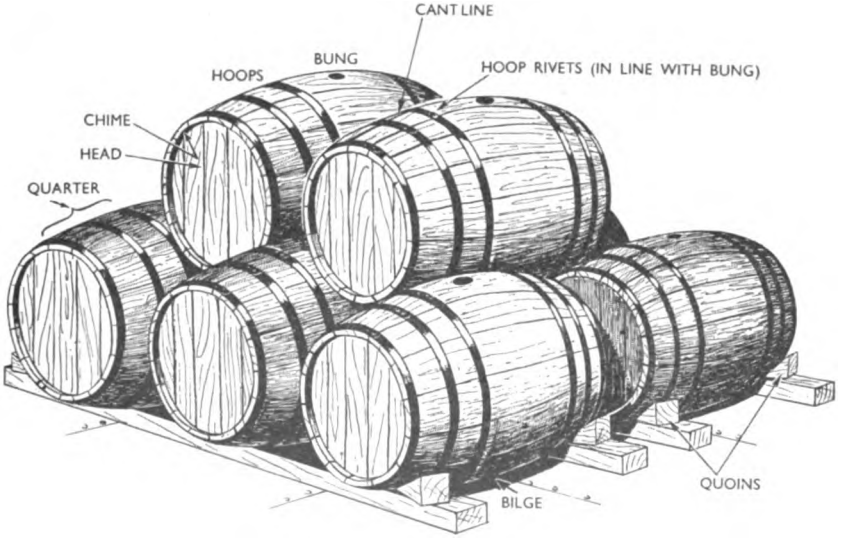

Fig. 139. Stowage of casks—bilge and cantline, bung up and bilge free

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from the centre outwards. Another general rule is to stow evenly and maintain as level a surface as possible as stowage progresses, but this may not be possible when stowing large items of irregular shape, or when cargo for different destinations has to be stacked in separate blocks.

Regularly shaped cargo of one type such as that contained in cases, bales, and bags, is stowed in tiers, and with some kinds dunnage may be necessary between tiers to distribute the weight of the upper tiers evenly over the lower tiers. When cargo for different destinations is stowed together it is either stacked in blocks separated from each other by horizontal planking kept in place by upright quartering, or by stepping down the cargo so that the removal of one cargo will not necessitate the restowage of the remainder.

Drums are stowed side by side vertically in tiers with their bungs uppermost, and casks should be stowed bilge to cantline with their bungs uppermost as shown in Fig. 139. Dunnage should be laid between tiers of drums, and the table below shows the maximum number of tiers for different types of casks.

MAXIMUM NUMBER OF TIERS FOR CASKS

TYPE OF CASK	CAPACITY IN GALLONS		MAXIMUM NUMBER OF TIERS
	British	*Wine*	
Butts or Pipes ...	105	126	3–4
Puncheons ...	60–100	72–120	4
Hogsheads ...	52½	63	6
Tierces	35	42	7

Heavy lifts should, when possible, be stowed lengthwise forward and aft, or diagonally over bearers, so that their weight is distributed evenly over the floors of the hold. If they have to be stowed athwartships the bearers must be laid over the floors of the hold and never between them.

When bulk cargo is stowed with general cargo the former is usually overstowed by the latter, but it is important to ensure that the two types are well separated by matting, cloths, tarpaulins or other dunnage.

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APPENDIX

Dimensions and strengths of Nylon Rope, and of Common Rigging Fittings

SIZES, WEIGHTS AND BREAKING STRESSES OF NYLON ROPE*

circumference	diameter	weight per 10 fathoms	breaking load
in.	*in.*	*lb.*	*ton cwt.*
$\frac{1}{2}$	$\frac{5}{32}$	0·54	— 5·8
$\frac{3}{4}$	$\frac{1}{4}$	1·04	— 10·7
1	$\frac{5}{16}$	1·80	— 17·85
$1\frac{1}{4}$	$\frac{13}{32}$	2·60	1 8·57
$1\frac{1}{2}$	$\frac{7}{16}$	4·04	2 1·1
$1\frac{3}{4}$	$\frac{9}{16}$	5·40	2 15·8
2	$\frac{5}{8}$	7·20	3 12·0
$2\frac{1}{4}$	$\frac{23}{32}$	8·60	4 10·0
$2\frac{1}{2}$	$\frac{13}{16}$	11·17	5 10·0
$2\frac{3}{4}$	$\frac{7}{8}$	13·17	6 14·0
3	$\frac{15}{16}$	15·83	8 —
$3\frac{1}{4}$	$1\frac{1}{16}$	18·40	9 6·0
$3\frac{1}{2}$	$1\frac{1}{8}$	21·75	10 16·0
$3\frac{3}{4}$	$1\frac{3}{16}$	24·75	12 10·0
4	$1\frac{1}{4}$	28·33	14 4·0
$4\frac{1}{2}$	$1\frac{7}{16}$	35·50	18 —
5	$1\frac{9}{16}$	44·10	22 4·0
$5\frac{1}{2}$	$1\frac{3}{4}$	53·33	26 14·0
6	$1\frac{7}{8}$	63·17	32 —
$6\frac{1}{2}$	$2\frac{1}{8}$	74·33	37 10·0
7	$2\frac{1}{4}$	86·17	43 10·0
8	$2\frac{9}{16}$	112·58	57 —
9	$2\frac{7}{8}$	142·17	72 —
10	$3\frac{3}{16}$	175·75	89 —

* At the time of going to press no standard specifications for nylon rope have been laid down, either by the Admiralty or by the British Standards Institute. The details given in this table are for "Viking" nylon ropes manufactured by British Ropes, Ltd. Details of cordage and wire rope are given in Chapter V of Volume II of this manual.

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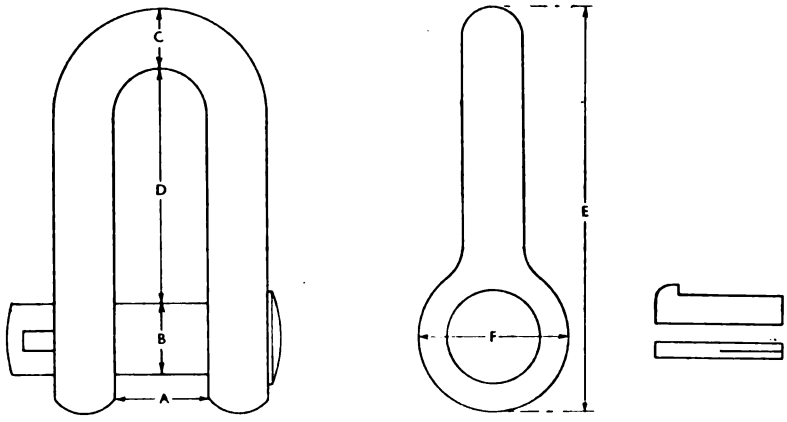
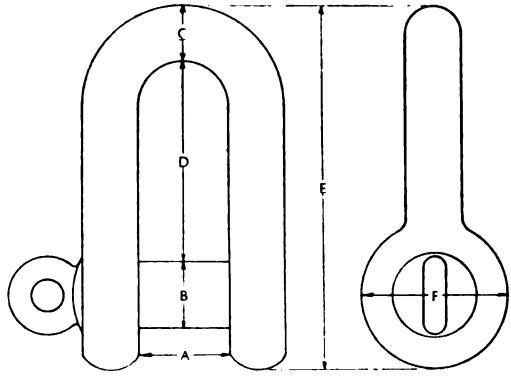


PATT No	5456	5457	5458	5459	5460	5461	5462	5463	5464	5465	5466	5467	5468	5469	5470	5471	5472[A]	5473
SIZE OF SHACKLE (INCHES)	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜
PROOF TEST IN TONS	½	1⅛	2	3⅛	4½	6⅛	8	10⅛	12½	15⅛	18	21⅛	24½	28⅛	32	36⅛	40½	45⅛
DISTANCE IN CLEAR (A) (INCHES)	11/32	⅜	13/32	1	1 5/32	1 23/32	1⅜	1 13/16	2	2 5/32	2 11/32	2⅜	2 15/16	3	3 5/32	3 11/32	3⅜	3 13/32
DIAMETER OF BOLT (B) (INCHES)	⅜	½	⅜	¾	1	1⅛	1¼	1⅜	1½	1⅝	1⅞	2	2⅛	2¼	2½	2⅜	2¾	2⅞
DIAMETER OF METAL (C) (INCHES)	¼	⅜	½	⅜	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜
INTERNAL LENGTH (D) (INCHES)	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½
EXTERNAL LENGTH (E) (INCHES)	1 13/16	2⅜	3 7/16	4⅛	5¼	6 3/16	6⅞	7⅜	7⅞	9½	10 5/16	11⅛	11 15/16	12⅝	13⅜	14 9/16	15⅝	16 5/16
EXTERNAL DIAMETER OF LUG (F) (INCHES)	⅜	15/16	1⅛	1 7/16	1⅝	2 3/16	2½	2 11/16	3⅛	3 7/16	3⅝	4 1/16	4⅜	4 11/16	5	5 5/16	5⅝	5 13/16

Rigging shackles—straight shackle with forelock



PATT. No.	5440	5441	5442	5443	5444	5445	5446	5447	5448	5449	5450	5451	5452	5453	5454
SIZE OF SHACKLE (INCHES)	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2
PROOF TEST IN TONS	½	1⅛	2	3⅛	4½	6⅛	8	10⅛	12½	15⅛	18	21⅛	24½	28⅛	32
DISTANCE IN CLEAR (A) (INCHES)	11/32	⅜	13/32	1	1 5/32	1 23/32	1⅜	1 13/16	2	2 5/32	2 11/32	2⅜	2 15/16	3	3 5/32
DIAMETER OF BOLT (B) (INCHES)	⅜	½	⅝	¾	1	1⅛	1¼	1⅜	1½	1¾	1⅞	2	2⅛	2¼	2½
DIAMETER OF METAL (C) (INCHES)	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2
INTERNAL LENGTH (D) (INCHES)	13/16	1⅞	1 15/16	2¼	2 13/16	3 7/16	3⅝	4 1/16	4½	4 13/16	5 7/16	5⅞	6 5/16	6¾	7 3/16
EXTERNAL LENGTH (E) (INCHES)	1¾	2½	3¼	4	4 13/16	5¾	6½	7¼	8	8 13/16	10⅛	10½	11¾	12	12 13/16
EXTERNAL DIAMETER OF LUG (F) (INCHES)	¾	1	1¼	1½	2	2¼	2½	2¾	3	3½	3¾	4	4¼	4½	5

Rigging shackles—straight shackle with screw bolt

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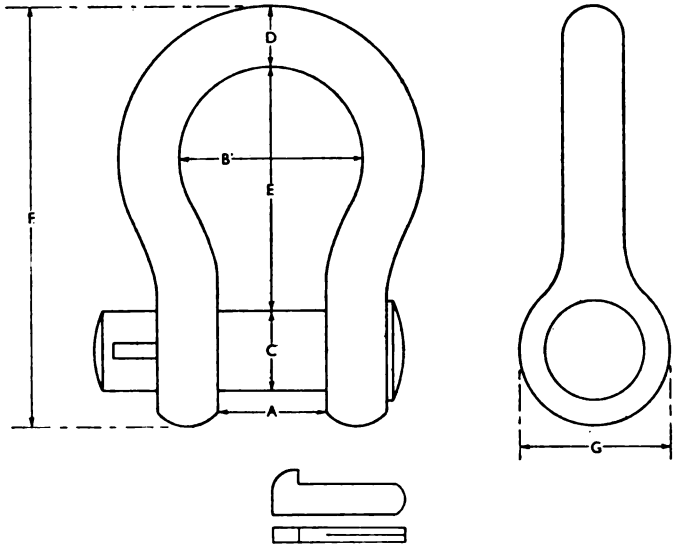

PATT. No.	5356	5357	5358	5359	5360	5361	5362	5363	5364	5365	5366	5367	5368	5369	5370	5371
SIZE OF SHACKLE (INCHES)	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2¼
PROOF TEST (TONS)	¼	⅜	1½	2	2½	4	5	6½	7½	9½	11½	13½	15½	17½	20	31½
DISTANCE IN CLEAR (A) (INCHES)	½	11/16	13/16	1⅛	1⅜	1⅜	1 11/16	2 1/16	2¼	2½	2¾	2 13/16	3 3/16	3⅜	3⅝	4½
DISTANCE AT (B) (INCHES)	¾	1⅛	1½	1⅞	2¼	2⅜	3	3⅜	3¾	4⅛	4½	4⅞	5¼	5⅝	6	7½
DIAMETER OF BOLT (C) (INCHES)	⅜	½	⅝	¾	1	1⅛	1¼	1⅜	1½	1¾	1⅞	2	2⅛	2¼	2½	3
DIAMETER OF METAL (D) (INCHES)	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2½
INTERNAL LENGTH (E) (INCHES)	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	10
EXTERNAL LENGTH (F) (INCHES)	1 11/16	2⅜	3 3/16	4½	5¼	6 1/16	6⅞	7 11/16	8½	9½	10 5/16	11⅛	11 13/16	12⅝	13¾	17
EXTERNAL DIAMETER OF LUG (G) (INCHES)	⅜	1	1⅛	1½	2	2¼	2½	2¾	3	3½	3¾	4	4¼	4½	5	6

Rigging shackles—bow shackle with forelock

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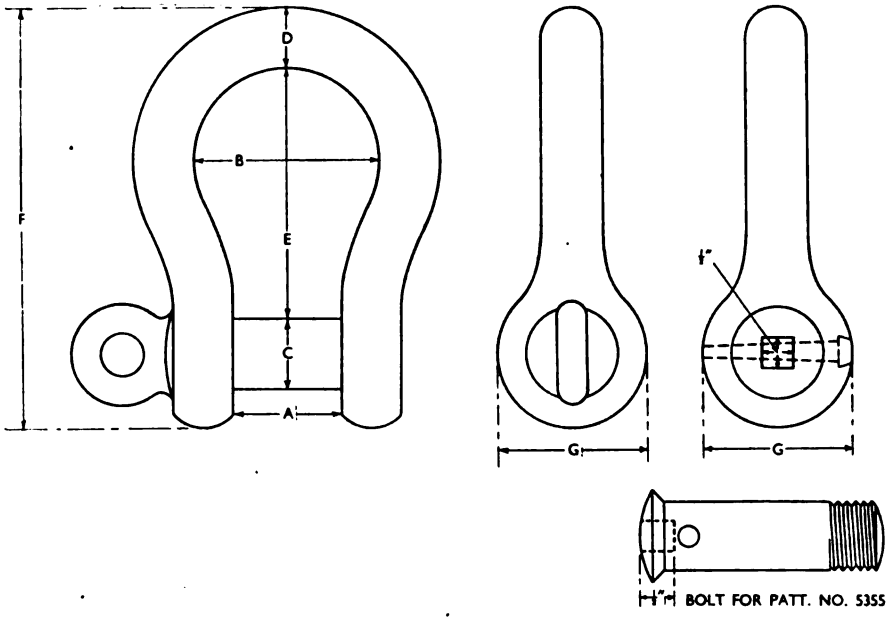

PATT. No.	5340	5341	5342	5343	5344	5345	5346	5347	5348	5349	5350	5351	5352	5353	5354	5355
SIZE OF SHACKLE (INCHES)	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	1
PROOF TEST (TONS)	¼	⅜	1½	2	2½	4	5	6½	7½	9½	11½	13½	15½	17½	20	5
DISTANCE IN CLEAR (A) (INCHES)	1/8	11/16	13/16	1⅛	1⅜	1⅜	1 13/16	2 1/16	2¼	2½	2¾	2 15/16	3 3/16	3⅜	3⅜	1 13/16
DISTANCE AT (B) (INCHES)	¾	1⅛	1½	1⅞	2¼	2⅜	3	3⅜	3¾	4⅛	4½	4⅞	5¼	5⅝	6	3
DIAMETER OF BOLT (C) (INCHES)	⅜	½	⅜	¾	1	1⅛	1¼	1⅜	1½	1¾	1⅞	2	2⅛	2¼	2½	1¼
DIAMETER OF METAL (D) (INCHES)	¼	⅜	½	⅜	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	1
INTERNAL LENGTH (E) INCHES)	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	4
EXTERNAL LENGTH (F) (INCHES)	1 1/2	2⅜	3 7/16	4½	5½	6 1/16	7⅞	7 11/16	8½	9½	10 5/16	11⅛	11 15/16	12⅝	13⅜	6⅜
EXTERNAL DIAMETER OF LUG (G) (INCHES)	¾	1	1½	1½	2	2½	2½	2¾	3	3½	3¾	4	4½	4½	5	2½

Rigging shackles—bow shackle with screw bolt

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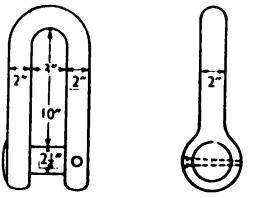
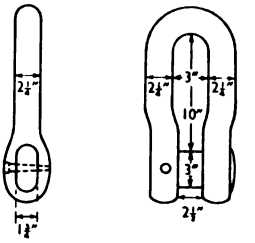


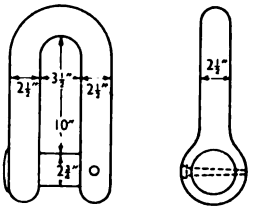
SHACKLE FOR TOWING

(FOR PATROL VESSEL) TESTED TO 32 TONS.
PATT NO N.901332



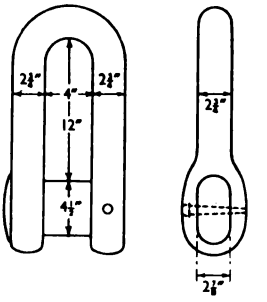
SHACKLE FOR TOWING

FOR USE WITH 5"& 3½" F.S.W.R TESTED
TO 40 TONS. PATT. NO. N.901336



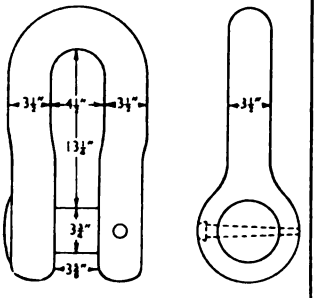
SHACKLE FOR TOWING

FOR USE WITH 5"& 3¼" F.S.W.R. TESTED
TO 56 TONS. PATT. NO. N 901340



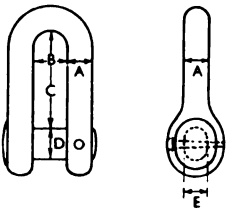
SHACKLE FOR TOWING

FOR USE WITH 6½"& 5½" F.S.W.R. TESTED
TO 72 TONS. PATT. NO. N.901344



SHACKLE FOR TOWING

FOR USE WITH 6¾ F S W R. TESTED
TO 85 TONS. PATT. NO N901356



SHACKLE FOR TOWING
SUPERSEDES ALL OTHER SHACKLES ON THIS PAGE

PATT. NO.	PROOF TEST (TONS)	DIMENSIONS					APPROPT. SIZE OF HAWSER	APPROPT. SIZE OF SLIP
		A	B	C	D	E		
1941	15	1⅜"	2"	5⅜"	1⅞"	1¼"	2"-2½"	1 1/16"-1½"
1942	20	1⅜"	2¼"	6½"	2⅛"	1⅜"	2¼"-3"	1⅜"-1⅝"
1943	30	1⅝"	2⅝"	8⅛"	2⅞"	1⅝"	3"-3½"	1 11/16"-1⅞"
1944	40	2¼"	3	9	3⅛"	1⅞"	3½"-4½"	1⅞"-1⅝"
1945	50	2½"	3⅜"	10¼"	3½"	2⅛"	4"-5"	2"-2 1/16"
1946	60	2⅝"	3⅝"	11½"	4"	2⅜"	4½"-5½"	2⅛"-2⅜"
1947	70	3"	4⅛"	12½"	4½"	2½"	5"-6"	2 1/16"-2 3/16"
1948	85	3⅜"	4⅜"	13½"	5"	3"	5½"-6½"	2 11/16"-2⅝"
1949	100	3¾"	4⅝"	14½"	5½"	3⅜"	6½"-8"	2 15/16"-3¼"

Towing shackles

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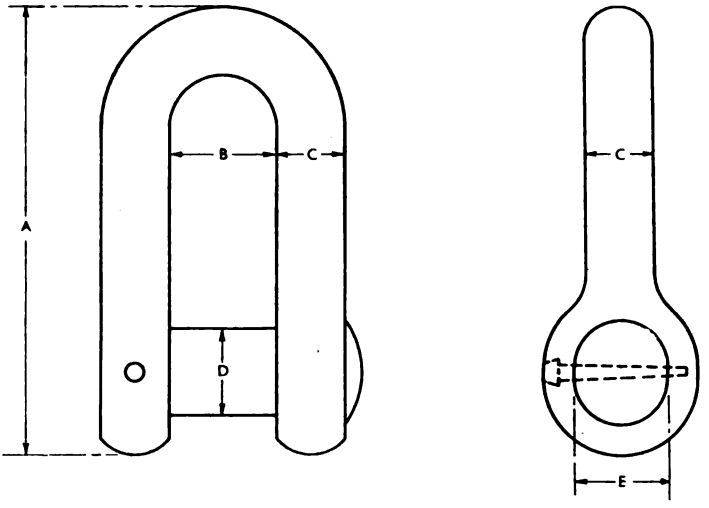
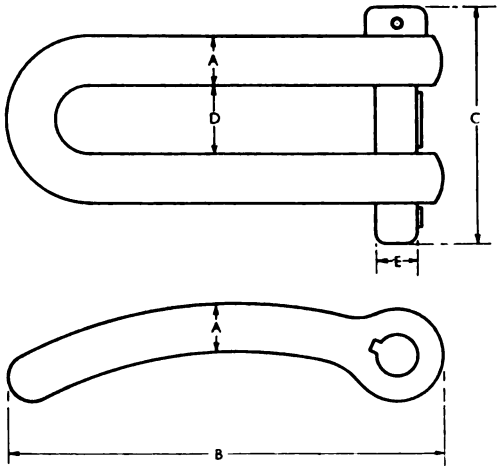


PATT. No.	SIZE OF CABLE IN INCHES	DIMENSIONS IN INCHES					TEST IN TONS
		A	B	C	D	E	
N.901714	$\frac{7}{8}$"	7·25	1·625	1·14	1·4	1·05	13$\frac{3}{4}$
N.901716	1"	7·5	1·875	1·3	1·6	1·2	18
N.901718	1$\frac{1}{8}$"	8·4375	1·875	1·46	1·8	1·35	22$\frac{3}{4}$
N.901720	1$\frac{1}{4}$"	9·375	2·1875	1·625	2·0	1·5	28$\frac{1}{2}$
N.901721	1$\frac{3}{16}$"	9·84	2·25	1·7	2·1	1·575	31
N.901722	1$\frac{3}{8}$"	10·3125	2·375	1·79	2·2	1·65	34
N.901723	1$\frac{7}{16}$"	11·25	2·5	1·875	2·3	1·75	37$\frac{1}{2}$

SPECIAL TOWING SHACKLE FOR DESTROYERS



PATT. No	SIZE OF CABLE TO BE USED WITH	PROOF LOAD IN TONS	DIMENSIONS IN INCHES				
			A	B	C	D	E
1938	1$\frac{15}{16}$" & BELOW	15	1$\frac{1}{2}$"	1' 3"	7$\frac{1}{4}$"	1$\frac{3}{8}$"	1$\frac{3}{8}$"
1938A	1$\frac{1}{2}$"—2"	25	1$\frac{5}{8}$"	1' 6$\frac{7}{16}$"	9"	2$\frac{1}{4}$"	1$\frac{5}{8}$"
1939	2$\frac{1}{16}$"—2$\frac{3}{8}$"	30	2$\frac{1}{4}$"	2'	11"	3"	2$\frac{1}{16}$"
1940	2$\frac{1}{2}$" & ABOVE	40	2$\frac{11}{16}$"	2' 0$\frac{7}{16}$"	1' 1"	3$\frac{3}{8}$"	2$\frac{3}{8}$"

JOGGLE SHACKLE

Destroyers' towing shackle, and joggle shackle.

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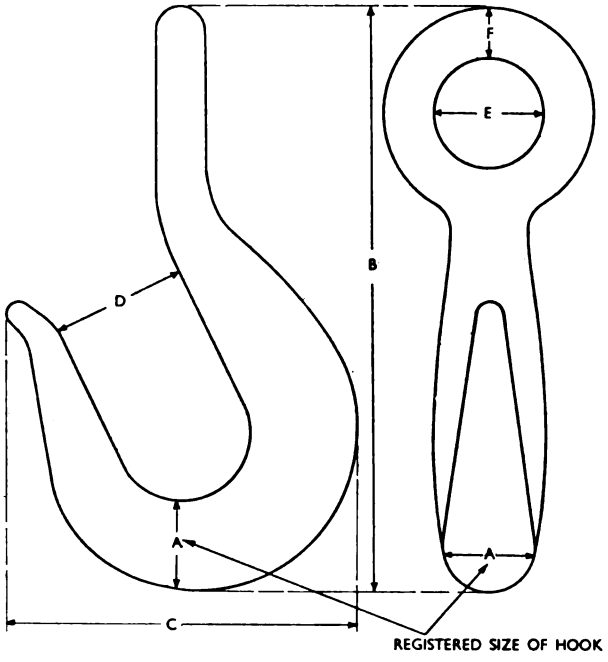

PATT. No.	4385	4386	4387	4388	4389	4390	4391	4392	4394	4395	4396	4397
PROOF TEST (TONS)	½	¾	¾	1	1½	2½	4	5½	7	8½	11	13½
REGISTERED SIZE (DIAMETER AT (A)) (INCHES)	⅜	½	⅝	¾	1	1¼	1½	1¾	2	2¼	2½	2¾
OVERALL LENGTH (B)' (INCHES)	2 7/16	3¼	4 1/16	4½	6½	8½	9¾	11⅜	13	14⅝	16¼	17⅞
OVERALL WIDTH (C) (INCHES)	1½	1¾	2	2 7/16	3½	4 1/16	4⅝	5 11/16	6½	7 5/16	8½	9
DISTANCE IN CLEAR (D) (INCHES)	9/16	¾	11/16	1⅛	1½	1⅞	2¼	2⅝	3	3⅜	3¾	4⅛
INTERNAL DIAMETER OF RING (E) (INCHES)	½	⅝	¾	1	1¼	1½	1⅞	2 3/16	2½	2 13/16	3⅛	3 7/16
DIAMETER OF METAL IN RING (F) (INCHES)	7/16	½	9/16	⅝	¾	⅞	1	1⅛	1	1⅛	1¼	1⅜

Tackle hooks

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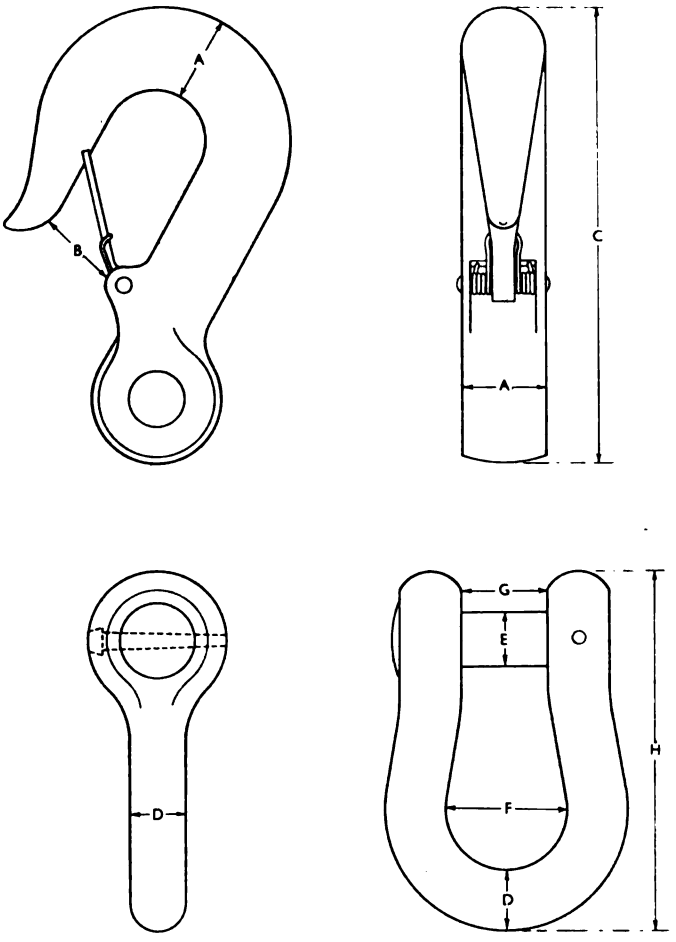

PATT. No OF SPRING 20968

HOOKS				SHACKLES			
PATT. No.	2096A	2097A	2098A	PATT. No.	2023	2024	2025
FOR USE WITH	3½" F.S.W.R.	2½" F.S.W.R.	4" F.S.W.R.	FOR USE WITH	3½" F.S.W.R.	2½" F.S.W.R.	4" F.S.W.R.
DIAMETER AT (A) (INCHES)	1¾"	1½"	2"	DIAMETER OF METAL (D)	1¼"	1"	1½"
DISTANCE IN CLEAR (B)	1⅜"	1⅛"	1⅞"	DIAMETER OF BOLT (E)	1¼"	1"	1¼"
LENGTH (C)	9½"	8"	11¼"	DISTANCE AT (F)	2½"	2⅛"	3"
PROOF TEST IN IN TONS	12	6	15	DISTANCE IN CLEAR (G)	1 13/16"	1⅜"	2½"
				LENGTH (H)	7 3/16"	6¼"	9 1/16"
				PROOF TEST IN TONS	12	6	15

Spring hooks and shackles for picking-up ropes

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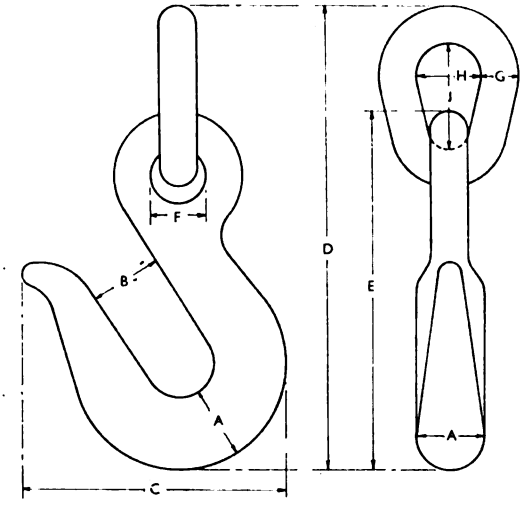
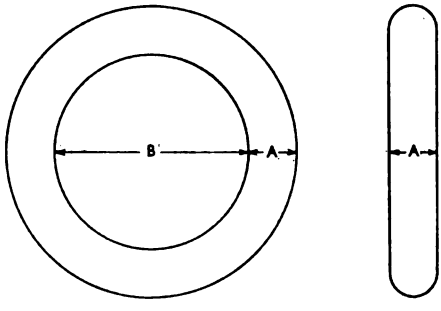


PATT No. HOOK WITH LINK	5392	5391	5390	5389	5388	5386	5384	5382	5380	5378	5376	5374	5372
PATT. No HOOK WITHOUT LINK	5413	5412	5411	5410	5409	5407	5405	5403	5401	5399	5397	5395	5393
SIZE OF HOOK (A)	½	⅝	¾	⅞	1	1¼	1½	1¾	2	2¼	2½	2¾	3
DISTANCE IN CLEAR (B)	½	⅝	¾	⅞	1	1¼	1½	1¾	2	2¼	2½	2¾	3
OVERALL WIDTH (C)	2	2½	3	3½	4	5	6	7	8	9	10	11	12
OVERALL LENGTH OF HOOK & LINK (D)	3½	4 1/16	4⅞	5 11/16	6½	8⅛	9¾	11⅜	13	14⅝	16¼	17⅞	19½
OVERALL LENGTH OF HOOK (E)	2½	3⅛	3¾	4⅜	5	6½	7½	8¾	10	11¼	12½	13¾	15
DIAMETER OF EYE (F)	9/16	9/16	11/16	11/16	11/16	13/16	1	1⅛	1¼	1 7/16	1 9/16	1 11/16	1 13/16
DIAMETER OF METAL IN LINK (G)	⅜	⅜	½	½	½	⅝	⅝	¾	1	1⅛	1¼	1⅜	1½
INTERNAL DIAMETER OF LINK (H)	¾	¾	1	1	1	1¼	1½	1¾	2	2¼	2½	2¾	3
INTERNAL LENGTH OF LINK (J)	1 3/16	1 3/16	2⅛	2⅛	2⅛	2 13/16	3½	3 15/16	4⅛	5	5 7/16	5⅞	6 5/16
PROOF TEST (TONS)	0·5	0·8	1·1	1·5	2	3·1	4·5	6·1	8	10·1	12·5	15·1	18
MINIMUM FAILING LOAD (TONS)	1·4	2·1	3·1	4·1	5·5	8·5	12·4	16·8	22	27·8	34·4	41·5	49·5

ALL DIMENSIONS IN INCHES

Hooks and links for boats' slings



PATT. No.	5059	5058	5057	5056	5055	5054	5053	5052	5051	5049	5047	5045	5043	5041
DIAMETER OF METAL (A) (INCHES)	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	2	2¼	2½	2¾	3
INTERNAL DIAMETER OF RING (B) (INCHES)	3	3½	4	4½	5	5½	6	6½	7	8	9	10	11	12
PROOF TEST (TONS)	2·3	3·1	4	5·1	6·3	7·6	9	10·6	12·3	16	20·3	25	30	36
MINIMUM BREAKING LOAD (TONS)	6·8	9·2	12	15·2	18·8	22·8	27	31·8	36·8	48	60·9	75	90	108

Rings for boats' slings

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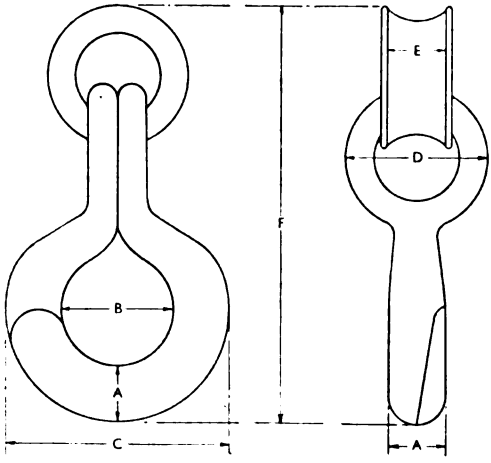
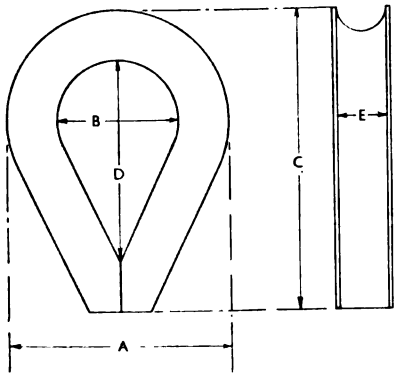


PATT. No.	4421	4422	4423	4425	4427
REGISTERED SIZE OF HOOK (A) (INCHES)	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{3}{4}$	1	$1\frac{1}{8}$
INTERNAL DIAMETER (B) (INCHES)	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{3}{4}$
EXTERNAL DIAMETER (C) (INCHES)	$1\frac{3}{4}$	$2\frac{1}{2}$	3	4	$5\frac{1}{2}$
EXTERNAL DIAMETER OF EYE (D) (INCHES)	$1\frac{1}{16}$	$1\frac{5}{16}$	$1\frac{7}{8}$	$2\frac{1}{2}$	$3\frac{7}{16}$
WIDTH OF SCORE (E) (INCHES)	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{11}{16}$	1	$1\frac{1}{4}$
OVERALL LENGTH (F) (INCHES)	3	$4\frac{1}{8}$	$5\frac{1}{4}$	7	$9\frac{1}{8}$
PROOF TEST (TONS)	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{4}$	$2\frac{1}{4}$

Calliper hooks



PATT No	5080	5081	5082	5083	5084	5085	5086	5087	5088	5089	5090	5091	5092	5093	5094	5095
SIZE OF WIRE (INCHES)	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	$6\frac{3}{4}$
EXTERNAL WIDTH (A) (INCHES)	1	$1\frac{7}{16}$	$1\frac{13}{16}$	$2\frac{3}{16}$	$2\frac{9}{16}$	$2\frac{15}{16}$	$3\frac{11}{16}$	$4\frac{3}{8}$	5	$5\frac{9}{16}$	$6\frac{3}{16}$	7	$7\frac{3}{8}$	$8\frac{1}{4}$	$8\frac{7}{8}$	$10\frac{3}{4}$
INTERNAL WIDTH (B) (INCHES)	$\frac{9}{16}$	$\frac{13}{16}$	$1\frac{1}{16}$	$1\frac{3}{8}$	$1\frac{9}{16}$	$1\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{1}{2}$	$2\frac{7}{8}$	$3\frac{1}{8}$	$3\frac{1}{2}$	4	$4\frac{3}{8}$	$4\frac{3}{8}$	5	$6\frac{1}{4}$
EXTERNAL LENGTH (C) (INCHES)	$1\frac{5}{16}$	$1\frac{7}{8}$	$2\frac{9}{16}$	$3\frac{3}{16}$	$3\frac{3}{8}$	$4\frac{1}{8}$	$5\frac{1}{4}$	$6\frac{1}{8}$	$7\frac{1}{16}$	$7\frac{7}{8}$	$8\frac{3}{8}$	$9\frac{3}{4}$	$10\frac{3}{8}$	$11\frac{1}{8}$	$12\frac{1}{4}$	$15\frac{1}{4}$
INTERNAL LENGTH (D) (INCHES)	1	$1\frac{7}{16}$	$1\frac{7}{8}$	$2\frac{5}{16}$	$2\frac{3}{4}$	$3\frac{1}{16}$	$3\frac{3}{4}$	$4\frac{3}{8}$	5	$5\frac{1}{2}$	$6\frac{1}{8}$	7	$7\frac{11}{16}$	$8\frac{1}{16}$	$8\frac{3}{4}$	11
WIDTH AT (E) (INCHES)	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{4}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{13}{16}$	1	$1\frac{1}{8}$	$1\frac{5}{16}$	$1\frac{7}{16}$	$1\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{15}{16}$	$2\frac{1}{8}$	$2\frac{1}{2}$

Thimbles for unserved wire rope

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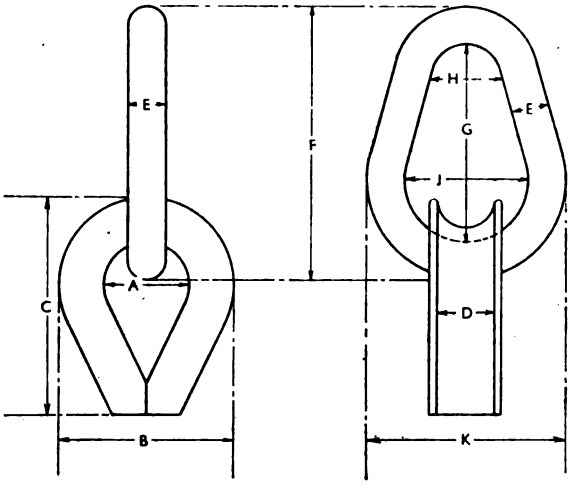

PATT. No.	THIMBLE WITH LINK	6410	6411	6412	6413	6414	6415	6416	6417	6418	6419	6420
	THIMBLE WITHOUT LINK	6410A	6411A	6412A	6413A	6414A	6415A	6416A	6417A	6418A	6419A	6420A
PROOF TEST OF LINK (TONS)		10½	13½	18	20	25	28	30	36	40	46	55
SIZE OF ROPE (INCHES)		8	9	10	11	12	13	14	15	16	18	20
INTERNAL WIDTH OF THIMBLE (A) (INCHES)		3¾	3⅞	4	4⅛	4¼	5⅛	5½	5⅞	6¼	7⅛	8
EXTERNAL WIDTH OF THIMBLE (B) (INCHES)		7¼	8	8⅝	9½	10⅛	11½	12	12¾	13½	15	17
EXTERNAL LENGTH OF THIMBLE (C) (INCHES)		9	10	11	11⅞	12⅞	13⅞	14⅞	15¾	16⅛	18⅜	21
WIDTH OF SCORE (D) (INCHES)		2¾	3⅛	3½	3⅞	4¼	4⅜	5	5⅜	5¾	6½	7¼
DIAMETER OF METAL IN LINK (E) (INCHES)		1⅜	1¾	2 1/16	2⅛	2⅜	2½	2⅝	2¾	3	3⅛	3½
EXTERNAL LENGTH OF LINK (F) (INCHES)		11⅜	11½	14¼	14⅞	16⅜	17½	18¾	19¼	21	22	24½
INTERNAL LENGTH OF LINK (G) (INCHES)		8⅛	8¾	10⅛	10⅜	11⅞	12½	13⅛	13¾	15	15¼	17½
WIDTH AT (H) (INCHES)		2⅞	3⅛	3⅜	3¾	4⅛	4⅜	4½	4⅞	5¼	5½	6⅜
WIDTH AT (J) (INCHES)		4⅞	5¼	6⅛	6½	7	7½	8	8¼	8¾	9½	10
EXTERNAL WIDTH OF LINK (K) (INCHES)		8½	8¾	10¼	10¾	11¾	12½	13¼	13¾	14¾	15¾	17

Thimbles and links for manila cordage

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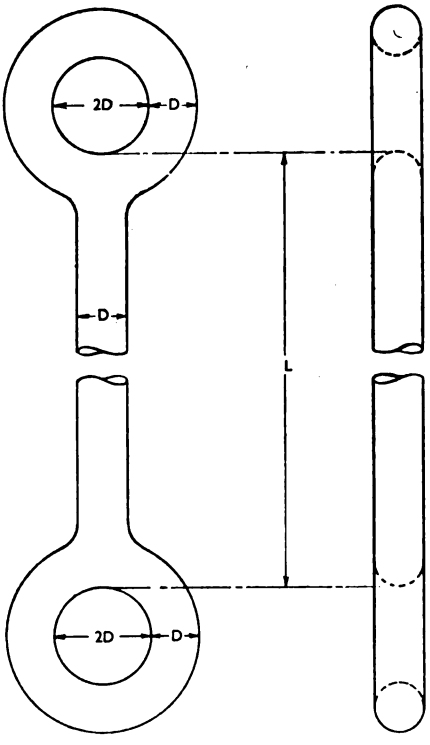
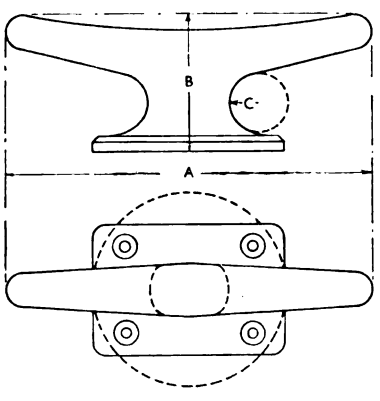


PATT. Nos	77b	78	79	80	81	82	83	84	85	86	87
DIAMETER D	$\frac{3}{8}$"	$\frac{1}{2}$"	$\frac{5}{8}$"	$\frac{3}{4}$"	$\frac{7}{8}$"	1"	$1\frac{1}{4}$"	$1\frac{1}{2}$"	$1\frac{3}{4}$"	$1\frac{3}{4}$"	$1\frac{3}{4}$"
LENGTH L	8", 12" 18"	9", 12" 18"	12", 18" 24"	18", 24" 30"	24", 30" & 36"	24", 30" 36" & 42"	30", 36" 42" & 48"	36", 42" 48" & 54"	60	48", 60"	48", 60"
PROOF LOAD IN TONS	$1\frac{3}{8}$	$2\frac{1}{2}$	$3\frac{7}{8}$	$5\frac{3}{8}$	$7\frac{3}{8}$	10	$12\frac{5}{8}$	$15\frac{3}{8}$	$18\frac{7}{8}$	$22\frac{1}{2}$	$30\frac{3}{4}$

Driven eye-bolts



	SECURED BY RIVETING								SECURED BY WELDING			
SHAPE OF BASE	CIR.	RECT.	CIR.	RECT.	CIR.	RECT.	CIR.	RECT.	RECT.	RECT.	RECT.	RECT.
PATT. No.	231	232	233	234	235	236	237	238	240	242	244	246
SIZE OF ROPE	$1\frac{1}{4}$	$1\frac{1}{4}$	2	2	$2\frac{1}{2}$	$2\frac{1}{2}$	3	3	$1\frac{1}{4}$	2	$2\frac{1}{2}$	3
LENGTH OF CLEAT (A)	$7\frac{1}{2}$	$7\frac{1}{2}$	10	10	$12\frac{1}{2}$	$12\frac{1}{2}$	15	15	$7\frac{1}{2}$	10	$12\frac{1}{2}$	15
HEIGHT OF CLEAT (B)	$2\frac{3}{16}$	$2\frac{3}{16}$	$3\frac{7}{16}$	$3\frac{7}{16}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{8}$	$5\frac{1}{8}$	$2\frac{3}{16}$	$3\frac{7}{16}$	$4\frac{1}{2}$	$5\frac{1}{8}$
RADIUS AT C	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{15}{16}$	$\frac{15}{16}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$\frac{11}{16}$	$\frac{11}{16}$	$1\frac{1}{8}$	$1\frac{3}{8}$

ALL MEASUREMENTS IN INCHES

Mild steel cleats

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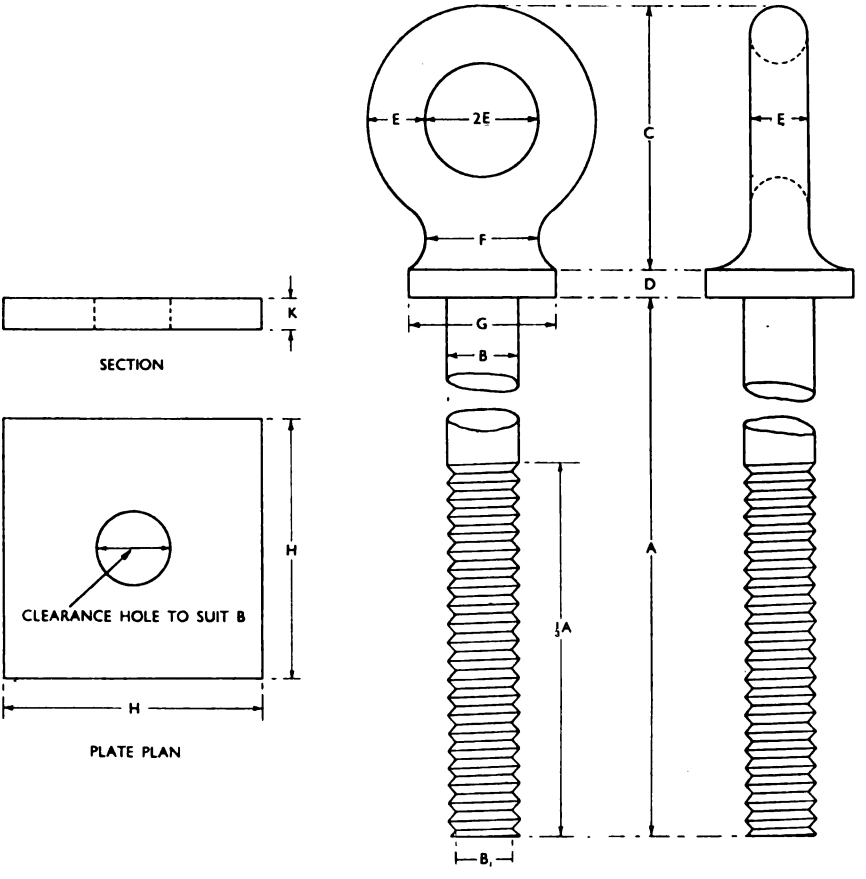

PATT No	A INS	BOLTS B INS	B1 INS.	C INS.	D INS	E INS	F INS.	G INS.	THREADS PER INCH	PLATES H INS.	K INS.
89	9, 8, 7, 6, 5	$\frac{1}{4}$	$\frac{3}{8}$	2	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{4}$	$1\frac{1}{16}$	8	$2\frac{3}{8}$	$3\frac{1}{16}$
90	10, 9, 8, 7	$\frac{3}{8}$	19/40	$2\frac{3}{16}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{7}{8}$	$1\frac{1}{2}$	$6\frac{1}{2}$	$2\frac{3}{8}$	$\frac{1}{2}$
91	12, 10, 9, 8	$\frac{1}{2}$	11/20	$2\frac{13}{16}$	$\frac{5}{16}$	$\frac{1}{8}$	$1\frac{1}{16}$	$1\frac{1}{2}$	5	$2\frac{3}{4}$	$\frac{1}{2}$
92	18, 14, 12, 10, 8	$\frac{7}{16}$	13/20	$3\frac{3}{16}$	$\frac{1}{16}$	$\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$4\frac{1}{2}$	3	$\frac{1}{2}$
93	18, 15, 12, 10, 8	1	$\frac{1}{2}$	$3\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{8}$	$1\frac{5}{16}$	$1\frac{15}{16}$	4	$3\frac{1}{8}$	$\frac{5}{16}$

Screwed eye-bolts

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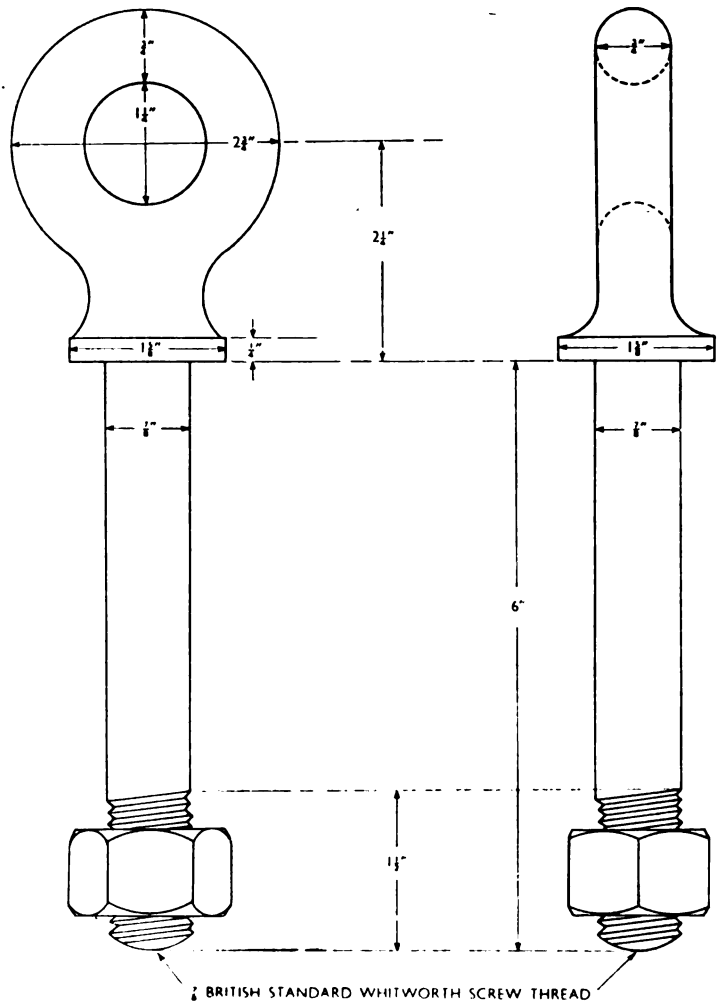
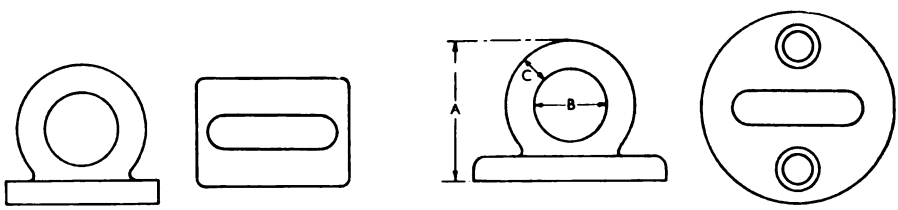


Single-ended eye-bolts—proof load 5 tons



SECURED BY WELDING

SECURED BY RIVETTING

PATTERN	RIVET	4000	4001	4002	4003	4004	4005	4007	4009	4011	4013
No.	WELD	4014	4015	4016	4017		4019	4021	4023	4025	4027
PROOF TEST IN TONS		1¼	3⅛	4⅜	7	9	12½	19½	28⅛	38¼	50
TOTAL HEIGHT (A) IN INCHES		1½	2	2½	3	3½	4	5	6	7	8
DIAMETER OF EYE (B) IN INCHES		¾	1	1¼	1½	1¾	2	2½	3	3½	4
DIAMETER OF METAL (C) IN INCHES		⅜	½	⅝	¾	⅞	1	1¼	1½	1¾	2
NUMBER OF SECURING RIVETS		2	2	2	2	2	4	4	4	4	6

Mild steel eye-plates

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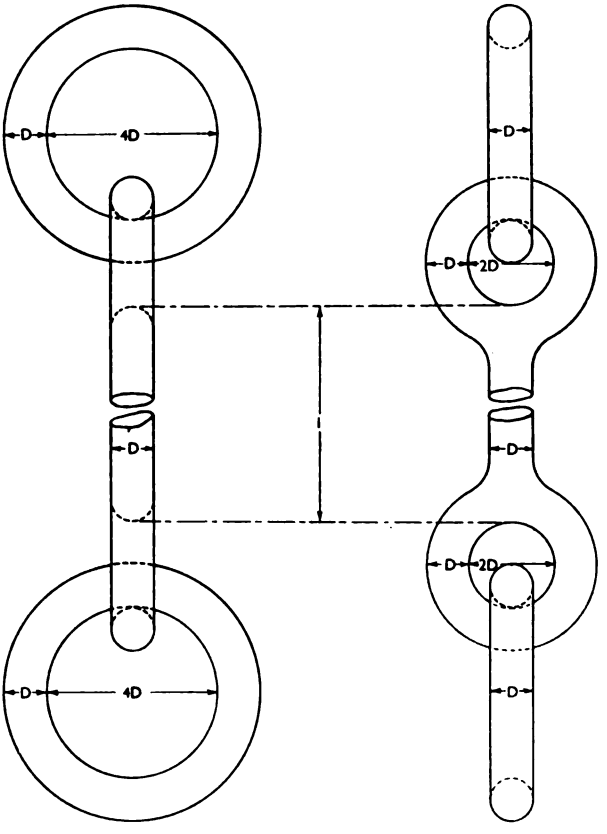

PATT Nos		95b	96	97	98	99	100	101	102	103	104	108
DIAMETER D		$\frac{1}{2}$"	$\frac{5}{8}$"	$\frac{3}{4}$"	$\frac{7}{8}$"	1"	1"	$1\frac{1}{8}$"	$1\frac{1}{4}$"	$1\frac{1}{2}$"	$1\frac{1}{2}$"	2"
LENGTH L		18" 12" 8"	18" 12" 9"	24" 18" 12"	30" 24" 18"	36" 30" 24"	42" 36" 30"	36"	48" 42"	48"	48" 36"	72"
PROOF LOADS IN TONS	RING	$\frac{3}{16}$	1	$1\frac{3}{16}$	$2\frac{1}{4}$	$3\frac{1}{16}$	4	$5\frac{1}{16}$	$6\frac{1}{4}$	$7\frac{3}{16}$	9	16
	BOLT	$1\frac{3}{8}$	$2\frac{1}{4}$	$3\frac{1}{8}$	$5\frac{3}{8}$	$7\frac{3}{8}$	10	$12\frac{3}{8}$	$15\frac{3}{8}$	$18\frac{1}{8}$	$22\frac{1}{4}$	40

Ring-bolts

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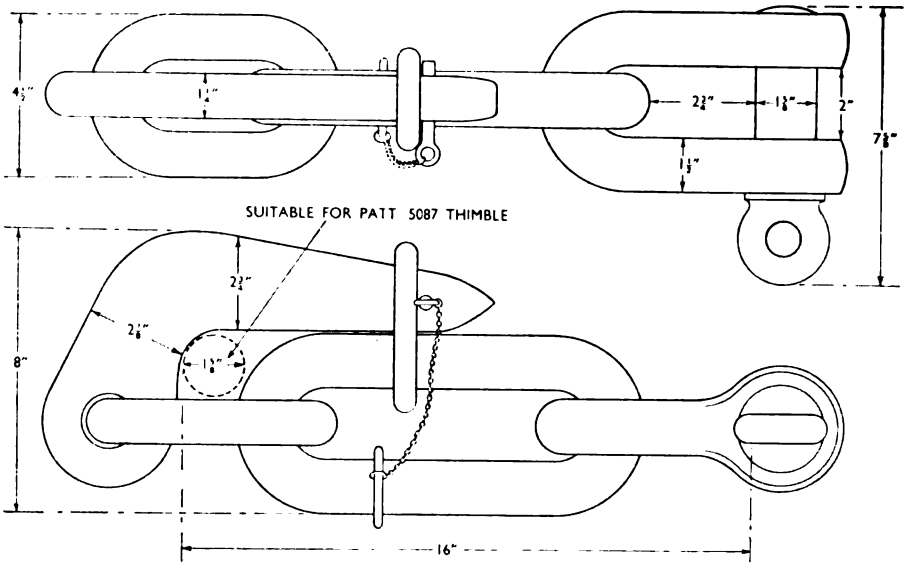
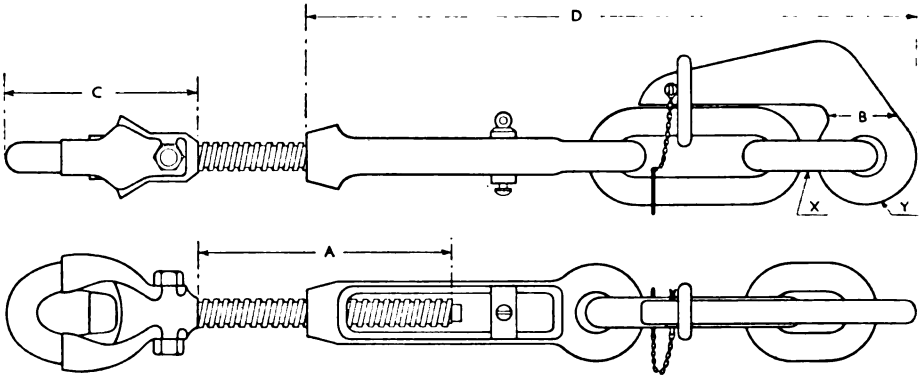


PROOF TEST 18 TONS

Slip and shackle for general use—Patt. No. 1915



NOTE:—THE SCREW WITHOUT THE LINK 'X' & SLIP 'Y' IS ALSO SUPPLIED. ALL DIMENSIONS & PROOF TESTS ARE AS FOR SCREW WITH SLIP EXCEPT FOR OVERALL LENGTH. SEE ILLUSTRATION PAGE 146 VOL I

PATT. No. SCREW WITH SLIP	51	52	53	54	55	55A	56	57	58	59
PATT. No. SCREW WITHOUT SLIP	60	61	62	63	64	65	66	67	68	69
PROOF TEST (TONS)	44·75	36·625	29·25	19·875	12·25	8·25	6·5	4·875	3·625	2·5
SUITABLE SIZE S.W.R. & F.S.W.R.			6½. 6. 5½	5. 4½	4. 3½	3		2½	2. 1¾	1½. 1¼ 1. ¾
LENGTH OF SCREW (A) (INCHES)	22	20	18	14¾	11¾	9½	8½	7½	6¼	5¼
MEASUREMENT AT (B) (INCHES)	7⅞	7⅛	6⅜	5¼	4⅛	3⅜	3	2⅝	2¼	1¾
LENGTH OF EYE (C) (INCHES)	17	15½	13½	11¼	9	7¼	6½	5⅛	4¼	4
LENGTH OF BOTTLE & SLIP (D) (INCHES)	53¼	47¼	43⅛	35¾	27½	22¾	20¼	17¾	15⅛	12¼

Screw slip for rigging (shrouds, stays, funnel guys, etc.)

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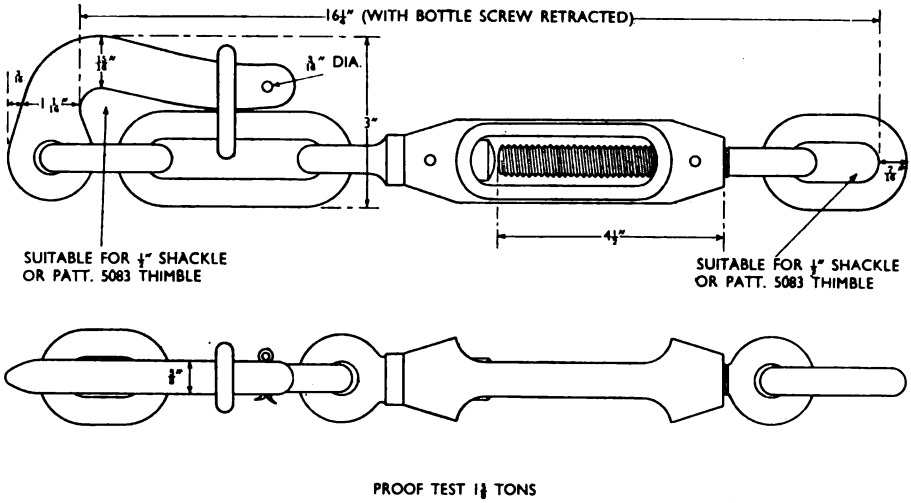
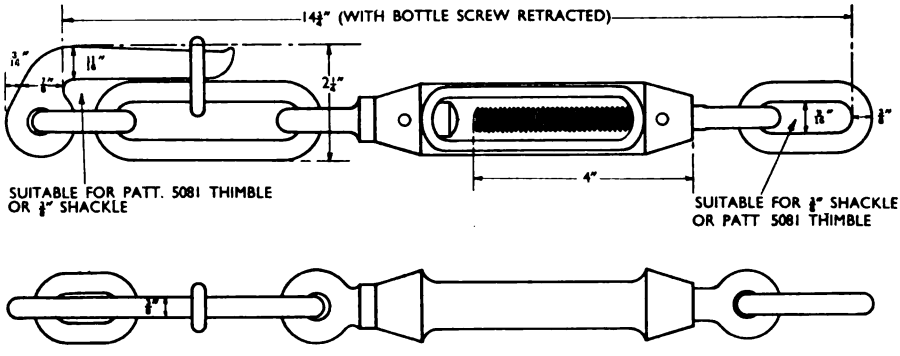


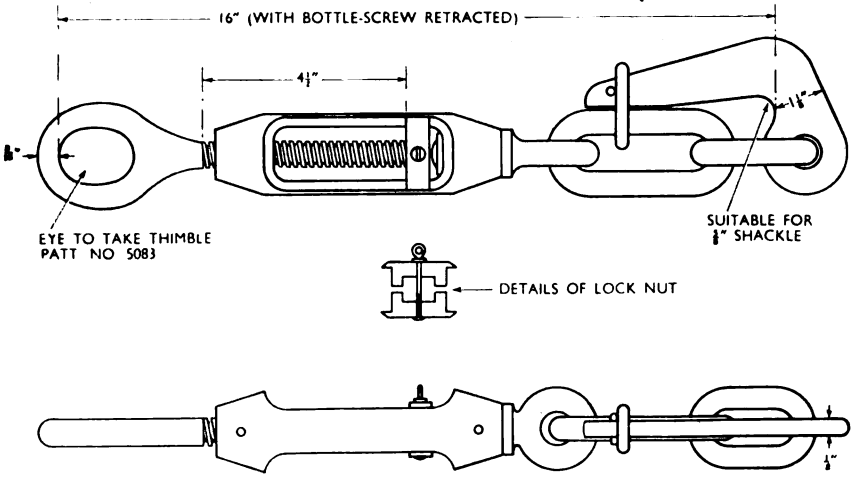
PROOF TEST 1⅛ TONS

Screw slip for guard-rails—Patt. No. 1916A



PROOF TEST ¾ TON

Screw slip for guard-rails—Patt. No. 1916



NOTE —THIS IS NOT A PATTERN NUMBERED ITEM BUT SHOULD BE NOTED EITHER IN THE RIGGING WARRANT OR THE LIST OF PORTABLE FITTINGS

PROOF TEST 2 TONS

Screw slip for destroyers' davit guys—special pattern

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INDEX

page

Abandoning ship :
Boats, provisioning for 271
Clothing, importance when .. 270
Life-saving equipment, maintenance for 268
Organisation for 273
Rations for 272
Remarks on 274
Training for 267

Aerials, wireless and radar, precautions 10

Air-supply terminals, for ventilation in warships 353

Alterations and additions (As & As), to ships 364

Anchor holdfast, for use with extempore derricks 217

Anchor work :
Amount of cable to be veered at single anchor 70
Anchoring and mooring :
in company in column formation 59
off a coral island 73
in deep water 72
in a strong river current and in a tidal stream 73
Clearing away anchors in pilotage waters 24
Coming to single anchor .. 71
Dragging :
emergency measures when .. 75
precautions against .. 5, 74
Letting go an anchor :
before going alongside .. 94
in a canal to correct a sheer 113
in harbour in an emergency .. 99
when mooring stern to a jetty 96
when turning short in harbour 80
when turning short in a river 101
Precautions when manœuvring in harbour 98
Riding out a gale at anchor .. 74
Weighing :
when in company in column formation 50
when hauling off a jetty .. 95
when moored stern to a jetty 97
when at single anchor .. 76
Yawing at single anchor, prevention of 74

page

Anchors :
Mooring, types and holding powers of .. 151, 161, 170
Ships', types and holding powers of 171

Anti-snatch type of light mooring 167

Anti-twisters, for use with tackles 217

Armament and torpedo stores 359

Armour, use of in warship construction 335

Asdic, use of in narrow waters .. 30

Auxiliary derrick, for raising derricks and sheers 220

Ballasting and topweight, effects of on ship stability .. 407

Bathing, over the side in harbour 14

Baulk holdfast, for use with extempore derricks .. 217, 233

Beams, functions of in ship construction 327

Berthing hawsers, use of .. 67

Bilge pumps, in warships :
Emergency 341
Fire-and-bilge 342

Blizzards, dangers of to stability of ship 126

Boats, O.O.W.'s responsibilities regarding :
Despatch boat 9
Provision of 8
Safety of 4

Boats, life, provisioning of .. 271

Books and forms for stationery 361

Brackets, functions of in ship construction 327

Breakdowns of engines or steering, action in 23

Bridge, O.O.W.'s responsibilities regarding :
Lay-out, knowledge of 15
Logs and notebooks, for use on 30

Digitized by Google

page

Broken stowage of cargo .. 440

Bulkheads, functions of in ship construction 323

Buoyancy :
- Centre of, in ships 399, 412, 420
- Of drums and casks 247

Buoys :
- Classification of, and pendants for buoys 151, 158
- Securing to a buoy 80
- Securing head and stern between two buoys 82
- Slipping from a buoy 81
- Slipping head and stern from two buoys 83
- Telephone mooring buoy .. 165
- Types of buoys 153

Buried holdfast, for use with extempore derricks .. 217, 233

Burning and welding, fire precautions 4, 261

Burns, first-aid for 264

Cable, chain—*see under* **Chain.**

Cable, telephone, provision of at moorings 165

Camp for castaways, siting and making of 288

Canals, manœuvring in—*see under* **Manœuvring**

Canteen stores 362

Cargo :
- Marking and measurement of 450
- Particulars of 440
- Provision of 439
- Separation of 442

Cargo stowage :
- Broken stowage 440
- Dunnage 440, 451
- Lading gang, composition of .. 450
- Planning of 439, 444
- Rigs of derricks for 438
- Ships plans, re-drawing for .. 441
- Stowage plan, example of .. 447
- Terms used in 434

Cargo vessels, description of .. 382

Castaways, after shipwreck, notes for 287

page

Chain cable :
- Amount to veer at single anchor 70
- Amount to veer when towing .. 131
- For buoy pendants 158
- For different classes of moorings 159
- Square link for moorings .. 151

Chain, data for use with extempore derricks and slings 231

Circulating pumps, Main, in warships 340

Claims for Salvage, remarks on 172

Classification societies for construction and insurance of merchant ships 389

Coconut trees, use of by castaways 288

Cofferdams, for salvage purposes 195

Collisions, International Regulations for Preventing, at Sea—see under *International*

Collision :
- Precautions against :
  - when at anchor 4
  - when manœuvring in company 19
  - when manœuvring in harbour 98
- Preventing :
  - action at sea and in narrow channels 29
  - action in emergency 99

Column formation :
- Anchoring when in 59
- Leaving harbour in 50
- Station-keeping when in .. 54
- Taking station in 51
- Unmooring and weighing when in 49

Combustion, Spontaneous, fire risk 261

Compressed air, use for salvage purposes 180

Concrete, for salvage purposes, uses of 179

Conning orders and procedure :
- Breakdowns 23
- Emergency 98
- Engine orders 21
- Wheel orders 22

Construction of warships :
- Armour 335

Digitized by Google

page

Construction of warships (*cont.*)
Connections, methods of :
riveting 307
welding 309
Materials for ship building :
steel and non-ferrous metals 304
strengths and tests of .. 305
Protective plating 337
Strength members and structures, functions of :
beams, brackets and pillars .. 327
bulkheads 323
decks 325
framing 314
inner and outer bottoms .. 321
Stresses experienced by ships .. 301
Submarines, construction of .. 337
Watertight sub-division .. 331

Cordage, data for use with extempore derricks and slings .. 230

Cross curves of stability 400, 402, 419

Death, signs of 284

Decks, functions of, in ship construction 325

Defects and defect lists, for warships 362

Definitions of terms used in :
Cargo stowage 434
Rule of the Road 32
Refitting 371
Wreck dispersal 200

Depth-charges for use in wreck dispersal :
Method of use 203
Precautions for 208

Derricks, rigs for cargo stowage 438

Derricks and sheers, for extempore handling of heavy weights :
Guys for 214
Heel tackles for 215
Holdfasts for 217
Lowering of 223
Precautions regarding 229
Provision of power for :
by man-power 225
by tackles 226
by winches 228

page

Raising of :
by auxiliary derrick 220
by manhandling 219
by moving lever 219
by standing lever 220
Shoes for 215
Spars for 229, 232
Stresses in, data and formulæ for estimating 235
Tackles for 226
Uses and limitations of .. 212
Walking of 223
Winches for 228

Despatch boat, use of in harbour 9

Destroyers :
Docking and undocking .. 109
Towing-pendants in 141

Displacement curves 421

Distress signals :
International 45
In lifeboats, precautions regarding 276

Docking and undocking :
Conditions required 104
Docking 106
Docking destroyers 109
Docking-down 107
Docking hawsers 105
Docking small vessels with considerable trim 109
Docking submarines 109
Entering the dock 106
Floating docks 109
Flooding-up 108
Preparations in the dock .. 105
Preparations in the ship .. 104
Undocking 109

Dockyard organisation .. 376

Dragging, at anchor .. 5, 74

Draining systems, in warships 345

Draught and change of draught, in ships 413, 416, 421

Dredging, for salvage, use of small vessels or craft 182

Dry docks—*see under* **Docking.**

Dunnage for cargo stowage 440, 451

Ejectors, for flood water, in warships 343

Electric Power, provision of in emergency tows 140

Digitized by Google

page

Electrical loading, changes in, fire risk 257

Electricity, static, fire risks .. 260

Emergency measures when :
Dragging at anchor 75
Manœuvring in harbour .. 98

Engines, main :
Breakdown, action in 23
Handling of 65
Orders for :
standard 21
in emergency 98

Equipment in warships :
Classification of 356
O.O.W.'s responsibilities in regard to 7

Explosives and fireworks, fire risks and precautions regarding 10, 258

Exposure, treatment of survivors suffering from 298

Fans, ventilation, in warships, sizes and outputs of 352

Fires, causes and sources of :
Burning and welding 261
Electricity, static 260
Harbour risks 261
Lightning and radar 261
Spontaneous combustion .. 261
Vapours, inflammable, seepage 260
Welding and burning .. 261
Wireless transmissions .. 261

Fire-fighting :
Equipment for, maintenance and stowage of 252
First-aid for burns 264
Gases, dangerous, toxic qualities 259
Harbour, precautions in .. 4
Hazards, additional in ships :
electrical loading, changes in 257
explosives and fireworks .. 258
gas cylinders 258
gases, dangerous, toxicity .. 259
liquid fuels, ignition of .. 257
Hose-nozzles, jet/spray, discharge rates of 256
Inflammable materials, stowage and treatment of 252
Merchant ships, arrangements in :
fixed installations 264
portable equipment 265

page

Operations, direction of 253–7
Parties and patrols for, organisation of 251
Pumps :
fixed 342
portable, types and capacities of 262–4
Stability of ship, preservation of 255
Training for 252

First-aid for :
Ailments common in lifeboats .. 284
Apparently drowned, the .. 283
Broken bones 282
Burns, scalds and blisters 264, 283
Shock 283
Snake-bite and stings 295
Survivors after rescue 298
Wounds 282

First-aid kit in lifeboats, contents and use of 281

Fish, poisonous and venomous, precautions for castaways 289–95

Floating docks 109

Flooding and counter-measures, remarks on .. 430

Flooding and pumping board, use of in warships 429

Flooding systems in warships .. 345

Flotation, centre of, in ships .. 413, 420, 423

Forms for stationery stores .. 361

Framing, methods and functions of in ship construction 314

Freeboard, effect on stability .. 409

Free-surface liquids, effects on stability 410

Frostbite, treatment of survivors suffering from 286, 299

Fuels, liquid, ignition of .. 257

GZ, or righting-lever, curves 401, 403, 408, 419, 425

Gangway staff, duties of .. 1

Gas :
Citadel in ships, ventilation arrangements 354
Cylinders, fire risk 258

Digitized by Google

page

Gases, dangerous, toxic qualities 259

Girding, of tugs 102

Girdling, for increased stability in ships 409

Graphs—*see under* **Tables.**

Gravity, centre of, in ships .. 396, 408, 412

Ground-tackle :
Of moorings 151
For salvage 182

Guys for use with derricks and sheers 214

Gyns, for extempore handling of heavy weights :
Ropeway, use with 223
Shoes for 215
Uses and limitations 212

Handling ships in company—*see under* **Manœuvring in company.**

Handling ships in heavy weather :
Avoidance of tropical revolving storms.. 124
Blizzards 126
Consideration of the crew .. 125
Effects of the waves on the motion of a ship 117
Effects of the wind 118
Handling a ship in a seaway .. 119
Making the ship seaworthy .. 124
Sea anchors 126
Seas 116
Use of oil to calm the sea .. 125

Handling ships in narrow waters (*see also under each of the following main headings*):
Docking and undocking .. 104
Manœuvring in a canal .. 110
Manœuvring in general .. 60
Manœuvring in harbour without tugs 69
Manœuvring with the help of tugs 102
Manœuvring in a tideway and in a river 99

Harbour, entering and leaving :
When entering, O.O.W.'s duties 30
When leaving :
in company 50
O.O.W.'s duties 16

page

Hawsers :
Berthing, use of.. 67
Docking, nomenclature of .. 105
Towing, composition of .. 127

Heel, angle of, when hoisting out heavy weights 411

Heel tackles for use with derricks and sheers 215

Holdfasts for use with derricks and sheers 217, 233

Hooks, data for use with extempore derricks and sheers 231, 458

Hose-nozzles, jet/spray, discharge rates of 256

Hull-and-fire pumps in warships 342

Hydrostatic curves 421

Ice, indications of at sea 25

Immersion foot, treatment of survivors suffering from 287, 299

Inclining experiment in ships 406

Inflammable materials, stowage and treatment of 252

Inner bottoms, functions of in ship construction 321

Insects, precautions against, for castaways 295

International Regulations for Preventing Collisions at Sea
Part A. Preliminary and Definitions 32
Part B. Lights and Shapes .. 33
Part C. Steering and Sailing Rules 41
Part D. Miscellaneous .. 44

Investigations by the O.O.W. .. 12

Keys, Important and Magazine, custody and issue 12

Landfalls, for survivors from shipwreck 287–8

Leak-stopping in salvage work 175

Levers for raising derricks and sheers 219, 220

Digitized by Google

page

Lifeboats :
Ailments of survivors in .. 284
Distress signals in, precautions regarding 276
Distribution of crew in .. 276
Drills for abandoning ship in .. 268
First-aid kit for.. 281
Handling of, when abandoning ship 274
Maintenance of 269
Navigation and sailing of .. 279
Rations for 271, 277
Rescue from 295
Survival in 275

Lifebuoys and lifebuoy sentry 18

Lifting craft for salvage .. 195

Lightning, fire risks .. 10, 261

Lights and shapes used in Rule of the Road 33

Lights, provision of in a towed ship 139

Load line regulations for merchant ships 390

Loading :
Effects of on ship-handling .. 63
Effects of on stability 417
Of cargo 439

Log, keeping a, when adrift in a lifeboat 280

Logs and notebooks for O.O.W. at sea 30

Longitudinal stability— *see under* **Ship stability.**

Looking after the ship by O.O.W. at sea 20

Lookouts :
In harbour on boats 7
At sea 19

Low visibility, action by O.O.W. at sea 24

Maintenance, ship (*see also* **Refitting**) :
Alterations and additions .. 364
Defects and defect lists .. 362
Maintenance :
notes on 368
ship's staff work for 366
surveys and tests involved in 366
Periodical surveys and tests, table of 378

page

Man overboard at sea, action by O.O.W. 27

Manœuvring in a canal :
Correcting a sheer 113
Disturbance of the water and its effects on the ship 110
Passing another ship 114
Speed of the ship 112
Steering the ship 111

Manœuvring in company :
Keeping a plot 59
Leaving harbour 50
Station-keeping 54
Tactical rudder 48
Taking station in the column .. 51
Taking-up and changing station 54
Turning at rest 50
Turning capabilities of ships .. 47
Turning definitions 46
Unmooring and weighing .. 49

Manœuvring in harbour, general remarks on :
Effects of loading 63
Effects of shallow water .. 64
Effects of trim 64
Effects of a wind 66
Gaining and losing speed .. 66
Handling of main engines .. 65
Judgment of speed and distance 69
Means of propulsion 60
Means of steering 60
Propeller action 61
Rudder action 62
Steering when going astern .. 63
Use of berthing hawsers .. 67

Manœuvring in harbour without tugs :
Anchoring, riding at anchor, and weighing 69
Entering and leaving harbour through a narrow entrance .. 95
Going alongside a jetty .. 83
Going alongside, and slipping from, a ship at anchor or secured to buoys 93
Letting go an anchor before going alongside 94
Mooring stern to a jetty .. 96
Precautions and action in emergency 98
Securing head and stern between two buoys 82
Securing to a buoy 80
Slipping from alongside with an anchor down 95
Slipping from a buoy 81

Digitized by Google

page

Manœuvring in harbour without tugs (*cont.*)
Slipping from head and stern buoys 83
Slipping from a jetty 91
Turning short 77
Turning short round an anchor 80
Unmooring when secured by the stern to a jetty 97

Manœuvring in harbour with the help of tugs :
Girding 102
Going alongside 102
Navigating narrow channels .. 104
Slipping from alongside .. 103
Turning short 103

Manœuvring in a tideway and in a river :
Going alongside, and slipping from, a jetty 100
Manœuvring in rivers 100
Passing through a narrow entrance 100

Mark buoys 153

Marks of respect by O.O.W. in harbour 13

Men, safety of, O.O.W.'s responsibilities regarding :
When aloft 10
When being embarked or disembarked 9
When working over the side .. 5
When bathing over the side .. 14

Merchant ships :
Cargo vessels, description of .. 382
Design of, factors affecting :
classification societies .. 389
general factors 387
load line regulations 390
watertight sub-division .. 392
Fire-fighting installations and equipment in 264
Tankers, description of .. 383
Tonnage measurement of .. 394
Types of 380

Messengers, use of in towing .. 141

Metacentre and metacentric height of ships :
Curves of 399, 421
Description of 397, 412
How to find the 423
Position of the 398

Miscellaneous regulations, Rule of the Road 44

page

Moment to change trim one inch 414, 421

Moorings :
Anchors for :
holding power of .. 170, 171
types of 151, 161, 170, 171
Buoys for :
classification of 158
pendants for 151, 158
types of 153
Classification of 157, 159
Hauling-off 163
Holding power of 160
Laying of :
anti-snatch light type .. 167
resilient three-arm type .. 169
Maintenance of 160
Parts of :
buoys 153
buoy-pendants and ground-tackle 151
Swamping a mooring 163
Telephone cables for, provision of 165
Types of 155

Mooring and unmooring :
In a gale, river, or tidal stream, and off a coral island .. 73
When stern to a jetty 96

Naval stores 357

Navigation and pilotage, by O.O.W. 23

Navigation and sailing in lifeboats 279

Night rounds :
In harbour 14
At sea 20

Non-ferrous metals used in shipbuilding 304

Nozzles, jet/spray, discharge rates of 256

Nylon rope, sizes, weights and breaking stresses of 453

Officer-of-the-Watch in harbour :
Gangway staff, duties 1
Responsibilities, list of 3

Digitized by Google

page

Officer-of-the Watch in harbour (*cont.*)
Responsibilities, remarks on :
appearance of ship and boats 7
bathing over the side .. 14
boats, provision of 8
despatch boat 9
equipment, care of 7
embarking men and stores .. 9
investigations 12
keys, custody and issue .. 12
marks of respect 13
night rounds 14
regulating staff 14
reports to the Captain .. 14
routine, ordering of 8
safety of boats 4
safety of men aloft 10
safety of men over the side.. 4
safety of ship, against collision, fire, storm, and tide 4
security of ship 11
subordinate officers, instruction of 14
taking over a watch 3
visual signalling, supervision of 11
watertight integrity, maintenance of 11
wireless and radar aerials, precautions 10

Officer-of-the-Watch at sea :
Bridge lay-out, knowledge of .. 15
Conning :
breakdowns 23
engine orders 21
wheel orders 22
Entering harbour 30
Ice, indications of 35
Leaving harbour 16
Lifebuoys and lifebuoy sentry 18
Logs and notebooks 30
Looking after the ship 20
Lookouts 19
Low visibility 24
Man overboard 27
Navigation and pilotage .. 23
Radar and asdic 30
Reports to the Captain .. 30
Rule of the Road 28
Seaboats 18
Signals 29
Station-keeping 28
Sunset 29
Taking over a watch 16
Watch on deck 18
Watertight integrity 19

Oil, use of to calm the sea 125, 139

Outer bottoms, method of construction 321

page

Pads and patches for salvage, construction of 175

Picket holdfast, for use with extempore derricks 217

Pillars, functions of, in ship construction 327

Pilotage and navigation by O.O.W. 23

Pitching, effects of trim on .. 417

Plot, keeping of when manœuvring in company 59

Pontoons for salvage 195

Power, provision of, for extempore derricks and sheers .. 225

Propellers :
Action of 61
Drag of 161
Trailing of, when in tow .. 139

Propulsion of ships 60

Protective plating used in warships 337

Pumping and flooding board, use of in warships 429

Pumps and pumping systems in warships :
Draining systems 345
Flooding systems 345
Pumping systems 343
Pumps, types of :
fixed 340
portable for fire-fighting 262–4
portable for salvage .. 173, 198
portable for pumping and flooding 342
Spraying systems 346
Valves and gearing for 346
Water service systems :
for fresh water 346
for salt water 343

Radar and radio :
Aerials, precautions regarding .. 10
Fire, risks of 10, 261
Navigation and pilotage, aids to 30
Reflectors in small craft in tow, use of 139
Rafts for extempore transportation of heavy weights 247
Rainwater, catchment of in lifeboats 280

Digitized by Google

page

Rations for survivors in lifeboats 272, 277

Refitting of warships (*see also* **Maintenance**) :
- Dockyard organisation .. 376
- Preparations for 373
- Reserve, preparations for acceptance into 374
- Terms used for 371
- Trials after 375

Regulating staff, O.O.W.'s responsibilities regarding .. 14

Regulations, International, for Preventing Collisions at Sea—see under *International*.

Reports to the Captain by O.O.W. :
- In harbour 14
- At sea 30

Rescue of survivors from shipwreck :
- Food and drink for survivors .. 298
- Methods and equipment used for 296
- Survivors, ailments, treatment of :
  - exposure 298
  - frostbite 286, 299
  - immersion foot .. 287, 299

Reserve, preparation of warships for entry into 373

Resilient-type three-arm mooring 169

Riding out a gale at anchor .. 74

Rigging fittings, common, dimensions and strength of .. 454

Righting-lever, or GZ, Curves 401, 403, 408, 419. 425

Righting moment, in ships .. 396

Rings, data for use with extempore derricks and sheers 231, 461

Rivers :
- Anchoring and mooring in .. 73
- Manœuvring in 100

Rivets and riveting in shipbuilding 307

Rolling, of ships, effects on stability 401

Ropeways, extempore :
- Erection of 223
- Spans of, stresses in 235
- Uses and limitations of 213

page

Routine, ship's, O.O.W.'s responsibilities regarding :
- In harbour 8
- At sea 20

Rudder :
- Action of 62
- Tactical 48
- Turning power and types of .. 60

Rule of the Road at Sea:
- International regulations—*see under International*
- Remarks on, for O.O.W.s .. 28

Safety of the ship :
- In harbour 4, 11
- In low visil ility .. 4, 24
- When manœuvring and in narrow waters 19
- At sea generally 20

Sailing and steering rules, Rule of the Road 41

Salvage :
- Claims for and legal aspects of .. 172
- Cofferdams for 195
- Compressed air, uses for .. 180
- Concrete, uses for 179
- Dredging by small vessels or craft, methods used for .. 182
- Examples of 185
- Lifting craft for 195
- Patches for, construction of .. 175
- Pontoons for 195
- Pumping, methods used for .. 173
- Pumps for 198, 340
- Vessels specially built and equipped for 198
- Of vessels afloat, first-aid for .. 173
- Of vessels beached or stranded 181

Sea anchors, remarks on .. 126

Seaboats, O.O.W.'s responsibilities regarding 18

Seas, effects of in rough weather 116

Seasickness in lifeboats, prevention of 276

Seawater, drinking of, in lifeboats, warning 280

Security, of ship, in harbour, O.O.W.'s responsibilities regarding 11

Digitized by Google

page

Shackles, data for use with extempore derricks and sheers 231, 454

Shallow water, effects of on ship-handling 64, 110

Shapes and lights used in Rule of the Road 33

Sheer, in a canal, correcting a .. 113

Sheering stresses, in ships .. 417

Sheers, for extempore handling of heavy weights—*see under* **Derricks.**

Ship construction—*see under* **Construction.**

Ship-handling—*see under* **Handling ships** and **Manœuvring.**

Ship, Safety of:
In harbour 4, 11
At sea 19, 20

Ship stability :
Longitudinal stability and trim :
centres of buoyancy and gravity 412
centre of flotation or tipping centre 413
draught, change of, salt to fresh water.. 416
loading and trim, remarks on 417
metacentre 412
moment to change trim one inch.. .. .. 414, 421
tons per inch immersion 413, 421
trim and change of trim .. 413
Preservation of stability, when fire-fighting 255
Stability data and their use :
for cargo ships 418
for damaged ships, flooding and countermeasures .. 430
for warships 427
Submarines, stability and trim of :
longitudinal and trim .. 433
transverse 431
Transverse stability :
at large angles of inclination 400
degrees of 399
inclining experiment .. 406
metacentre and metacentric height 397–8
remarks on 407
righting moment 396
rolling 401

page

Shipwreck, survival after—*see under* **Survival.**

Shoes for use with derricks and sheers 215

Signals, O.O.W.'s responsibilities regarding :
In harbour 11
At sea 29

Signals, distress :
International regulations .. 45
In lifeboats, precautions regarding 276

Six-knot-minute-rule for speed of ships 56

Sleighs for transporting heavy weights :
Handling of 288
Types of 236

Small vessels and craft :
Docking those with considerable trim 109
Towing, preparation for .. 140

Snakes and snake-bites, precautions for castaways.. .. 295

Spans, for ropeways, tensions in 235

Spars, for extempore derricks, gyns and sheers :
Buoyancy of 247
Safe loads and thrusts for 232–3
Timber for 239
Weight of, per cubic foot .. 234

Speed of ships :
When anchoring 71
In a canal 112
Gaining and losing 66
In low visibility 41
Judgment of 69
When manœuvring in company:
reduction allowances .. 51
" six-knot-minute-rule " .. 56

Spontaneous combustion, fire risk 261
Spraying systems in warships 346

Stability statement 427

Stability of ships—*see under* **Ship stability.**
Stationery stores 361

Station-keeping :
General remarks on .. 28, 54
Keeping station in column .. 56
Keeping station on a bearing .. 58

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page

Station-keeping (*cont.*)
Keeping station when anchoring 59
Taking station in the column .. 51
Taking-up and changing station 54
Turning in succession in column 57

Standing derrick, extempore .. 213

Steel, types used for shipbuilding 304

Steering :
Breakdown of, procedure .. 23
In a canal 111
Means of.. 60
When going astern 63

Steering and sailing rules,
Rule of the Road 41

Stores :
Armament and torpedo .. 359
Canteen 362
Embarking and disembarking, precautions regarding .. 9
Inflammable, stowage of .. 252
Naval 357
Stationery, books and forms .. 361
Victualling 360

Storms, tropical revolving, avoidance of 124

Stowage of cargo—*see under* **Cargo.**

Stowage plan, example of .. 447

Stresses :
In derricks, gyns and sheers .. 230
In ships 301

Submarines :
Construction of 337
Docking and undocking .. 109
Securing a towrope in 137
Stability of 431

Subordinate officers, instruction of by O.O.W. 14

Sunset, at sea, O.O.W.'s duties .. 29

Surveys and tests of equipment in warships 366, 378

Survival after Shipwreck :
Castaways, notes for :
antidotes for poisonous bites and stings 295
camp, siting and making of 288
coconut trees, uses of .. 288
fishing and poisonous fish 289–95
insects, precautions against.. 295
land, proximity, indications of 287

page

landing, making a 288
natives, relations with .. 288
snakes, precautions against.. 295
water, provision of 288
Crew of lifeboat :
distribution of 276
protection and comfort of .. 278
routine and duties of .. 277
Death, signs of 284
Distress signals, precautions regarding 276
First-aid for :
ailments common in lifeboats 284
apparently drowned, the .. 283
broken bones 282
burns, scalds and blisters .. 283
shock 283
snake-bites and stings .. 295
wounds 282
First-aid kit, contents and use of 281
Log, keeping of a 280
Miscellaneous matters 280
Navigation and sailing.. .. 279
Rainwater, catchment of .. 280
Rations, custody and issue of.. 277
Seasickness, prevention of .. 276
Seawater, drinking of 280
Swimmers, aid to, when abandoning ship 276
Urine :
drinking of 280
passing, difficulty in 285
Weapons, custody of 276

Swimmers, aid to, after abandoning ship 276

Swinging derrick, extempore.. 212

Tables and graphs :
Anchoring, amount of cable to be veered when 70
Anchors, holding powers of 170, 171
Depth charges for wreck dispersal, inshore safety limits 209
Derricks, sheers, and gyns, stresses in parts of 235
Fire-hoze nozzles, quantities of water discharged by.. .. 256
Fittings in ships for use in towing, strengths of 135
Gases and vapours, toxic quantities of 260
Maintenance of equipment, periodical surveys and tests for 378
Moorings :
anchors for, holding powers of 171
buoys and buoy pendants for 158
classes of 159
pulls exerted by ships on .. 161

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page

Tables and graphs (*cont.*)
Pumps, portable, for salvage, sizes, types and capacities of 198
Rations for survivors in lifeboats 272
Ship-building materials, strengths of 305
Spans, sizes, tensions and safe working loads of 236
Spars, for use with derricks, sheers and gyns, safe loads of 232
Speed, of ships, gaining and losing 67
Surveys and tests of equipment, periodical 378
Tackles, mechanical advantages and velocity ratios of .. 227
Tankers, operational data for .. 387
Timber, weight per cubic foot .. 234
Towing :
factors of safety of F.S.W.R. 129
factors of safety of E.S.F.S.W.R. 130
length of towrope and depth of bight 132
pulls for various speeds .. 128
Ventilating fans, sizes and outputs.. 353
Victualling stores, musters of .. 361

Tackles for use with derricks, gyns, and sheers .. 226, 231

Tactical rudder 48

Tankers, description of 383

Telephone cables, provision at moorings 165

Terminals, air-supply, for ventilation in warships 353

Terms, various, definitions of—*see under* **Definitions.**

Tests and surveys of equipment in warships 366, 378

Tideway :
Anchoring and mooring in a .. 73
Manœuvring in a 100

Timber, strength of, for use with derricks, gyns and sheers 229, 232, 233

Tipping centre, in ships 413, 420, 423

Tonnage measurement of merchant ships 394

page

Tons-per-inch-immersion 413, 421

Topweight, removal of for ship stability 407

Torpedo stores 359

Towing, in harbour 103

Towing, at sea :
Aids and preparations for :
electric power, provision of .. 140
lights 139
messengers 141
oil, use of in rough weather 139
propellers, trailing of .. 139
radar reflectors 139
slipping and buoying the towrope 139
small vessels, preparation of for towing 140
towing-pendants in destroyers 141
Connecting and securing the towrope :
bad nips and chafe, prevention of 134
connecting links 134
fittings in ships, strength of 135
securing the tow in small craft 138
securing the tow in ships .. 136
securing the tow in submarines 137
Establishing contact and passing the towrope :
attitude and drift of a disabled ship 142
establishing contact by boat, grass-line and gunline 142–3
Taking in tow :
an anchored and disabled ship off a lee shore 149
a ship alongside 148
a stranded ship 148
Taking up the tow and towing 144

Yawing :
correcting a yaw 147
effects of wind and sea, trim, list, and underwater projections 145

Towropes :
Composition of 127
Depth of bight in .. 132, 141
Graphs for, use of 132
Length of 131
Selection of 131
Strength of 127
Summary of requirements for 133

Transverse stability—*see under* **Ship stability.**

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page

Trials, of warships after refitting 375

Trim :
When docking and undocking 104, 109
Effects when loading cargo .. 414
Effects in a seaway 119
Effects on shiphandling .. 64
Effects on stability 417
Effects when in tow 145
Effects when pitching at anchor 74
Moment to change trim by one inch 414
Of submarines 433
Tables for 422

Tropical revolving storms, avoidance of 124

Tugs, use of when manœuvring in harbour 102

Turning, of ships :
Capabilities of 47
Definitions 46
At rest when in column formation 50
In a seaway 122
Short in harbour 77
Short in a river 101
Short round an anchor .. 80
Short with tugs 103

Undocking 109

Unmooring and weighing :
When in company 48
When secured by the stern to a jetty 97

Urine :
Drinking of, by survivors, warning 280
Passing of, difficulty in, by survivors 285

Valves and gearing for pumping and spraying systems 346

Vapours, inflammable, fire risk 257, 260

Vehicles, transportation ashore by floating 249

Ventilation, in warships :
In arctic waters and in the tropics 349
Fans for 352
Gas citadel, arrangements of .. 354
Methods of 350
Organisation for 354
Terminals, air-supply, for .. 353
Watertight integrity, preservation of 354

Victualling stores 360

Walking derricks and sheers .. 223

Warship construction—*see under* **Construction.**

Watch, taking over by O.O.W. :
In harbour 3
At sea 16

Watchkeeping duties :
In harbour 1
At sea 15

Watch on deck at sea 18

Water, for drinking, in lifeboats 288

Water service systems in warships :
For fresh water 346
For salt water 343

Watertight integrity :
In harbour 11
At sea 19
In ventilation systems 354
Maintenance of, by O.O.W. :
in harbour 11
at sea 19

Watertight subdivision :
Of merchant ships 392
Of warships 331

Waves, effects on motion of ship 117

Weapons, custody of, in lifeboats 276

Weighing anchors :
In a gale 75
In normal circumstances .. 76
When in company 48
When moored stern to a jetty 97
When slipping from a jetty with an anchor down 95

Weights, heavy, extempore handling of :
With gyns, derricks, sheers and ropeways 212
By rafts 247
By sleighs 236

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page

Welding :
Fire risks 4, 261
Methods used in shipbuilding .. 309

Wheel orders :
In emergency 98
Standard 22

Winches, for use with derricks, gyns and sheers 228

Wind :
Effects of in rough weather .. 118
Effects of in ship-handling 66, 86
Going alongside in a wind .. 86
Securing to a buoy in a wind .. 81
Slipping from alongside in a wind 90
Turning short in a wind .. 78

Wire rope:
Factors of safety for towing 129, 130
Data for use with extempore derricks and sheers 231

page

Wireless aerials, precautions .. 10

Wireless transmissions, fire risks 261

Wreck dispersal :
Depth-charges, uses of 203
Firing charges, methods used for:
laying and firing by boat .. 204
laying and firing from the vessel 205
General remarks on 200
Locating and marking a wreck 201
Methods employed 203
Safety precautions 208
Surveying a wreck 203
Sweeping over a wreck 209
Terms used 200

Yawing :
At anchor, prevention of .. 74
In tow, effects and correction of 145–7

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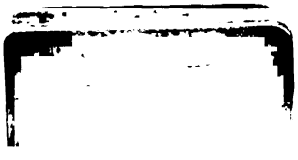

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